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Special edition within the scope
of Technical Cooperation in the field
of Vocational Training

# Tables for the Metal Trade

Deutsche Gesellschaft
für Technische Zusammenarbeit
(GTZ) GmbH

# Tables for the Metal Trade

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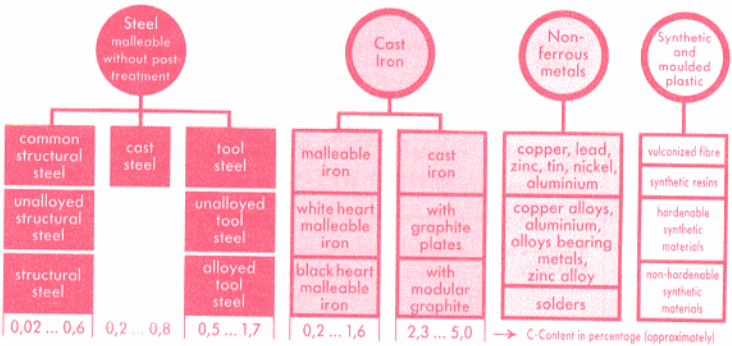
# MATERIALS

## Classification and categories




## Properties of materials

### Elements (selection)

### Densities – Melting points – Coefficient of linear (thermal) expansion

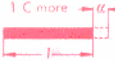
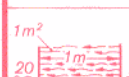
| Symbol | Element | Density $\varrho$ g/m³ | Melting or freezing point °C | Coefficient of linear (thermal) expansion $\alpha \cdot 10^{-6}$ m/m K |
|---|---|---|---|---|
| Ag | Silver | 10.5 | 961 | 20 |
| Al | Aluminium | 2.7 | 660 | 24 |
| Au | Gold | 19.3 | 1063 | 14 |
| Ba | Barium | 3.6 | 726 | 19 |
| Be | Beryllium | 1.85 | 1283 | 12 |
| Bi | Bismuth | 9.75 | 271 | 12 |
| C | Carbon | | | |
| | Graphite | 2.25 | 3550 | 8 |
| | Diamond | 3.52 | 3600 | 1 |
| Ca | Calcium | 1.55 | 850 | 22 |
| Cd | Cadmium | 8.64 | 321 | 31 |
| Ce | Cerium | 6.8 | 804 | |
| Co | Cobalt | 8.9 | 1492 | 14 |
| Cr | Chromium | 7.2 | 1900 | 8.5 |
| Cu | Copper | 8.9 | 1083 | 17 |
| Fe | Iron | 7.86 | 1535 | 12 |
| Ir | Iridium | 22.6 | 2454 | 6.6 |
| K | Potassium | 0.86 | 63 | 84 |
| La | Lenthanum | 6.18 | 826 | |
| Li | Lithium | 0.53 | 180 | 58 |
| Mg | Magnesium | 1.74 | 650 | 26 |
| Mn | Manganese | 7.5 | 1244 | 23 |
| Mo | Molybdenom | 10.21 | 2610 | 5 |
| Na | Sodium | 0,97 | 98 | 71 |
| Nb | Niobium | 8.4 | 2470 | 7 |
| Ni | Nickel | 8.9 | 1453 | 13 |
| P | Phosphorus | 1.82 | 44 | 124 |
| Pb | Lead | 11.35 | 327 | 29 |
| Pt | Platinum | 21.45 | 1769 | 9 |
| Ra | Radium | 6.0 | 700 | |
| S | Sulphur | 2.06 | 113 | 64 |
| Sb | Antimony | 6.69 | 630 | 11 |
| Se | Selenium | 4.3 | 220 | 37 |
| Si | Silicon | 2.4 | 1420 | 7 |
| Sn | Tin | 7.3 | 232 | 23 |
| Ta | Tantulum | 16.6 | 2990 | 7 |
| Th | Thorium | 11.7 | 1820 | 11 |
| Ti | Titanium | 4.52 | 1668 | 9 |
| U | Uranium | 18.7 | 1890 | |
| V | Vanadium | 5.96 | 1730 | |
| W | Tungsten | 19.27 | 3380 | 4 |
| Zn | Zinc | 7.13 | 420 | 30 |
| Zr | Zirconium | 6.5 | 1852 | 14 |
| Hg | Mercury | 13.5 | – 39 | 181 |
| $Cl_2$ | Chlorine | | – 101 | |
| $H_2$ | Hydrogen | | – 259 | |
| He | Helium | | – 272 | |
| $N_2$ | Nitrogen | | – 210 | |
| Ne | Neon | | – 249 | |
| $O_2$ | Oxygen | | – 219 | |

Density = mass per unit volume $\varrho = \frac{m}{V}$ (g/cm³, kg/dm³)

Example of the coefficient of linear (thermal) expansion of aluminium
$\alpha = 24$ m/mK, Length $l = 1200$ mm, temperature difference $\Delta T = 60$ K
Linear expansion $\Delta l = L \cdot \alpha \cdot \Delta T = 1.2 \text{ m} \cdot 24 \cdot 10^{-6} \text{ m/mK} \cdot 60 \text{ K} = 1.728 \text{ mm}$

For solids, the volumetric coefficient of thermal expansion is $\gamma = 3\,\alpha$

# Notations of material properties

| | | |
|---|---|---|
| $\varrho$ | **Density** = Mass / volume $\left(\frac{g}{cm^3}\text{ or }\frac{kg}{dm^3}\right)$<br>$\varrho$ = m / V (for gases: kg/m³) | DIN 1306 (Dec. 71) |
| $J$ | **Quantity of heat** = thermal energy in SI-unit: J (Joule)<br>1 J = 1 Nm = 1 Ws<br>thermal energy = mechanical energy = electrical energy | |
|   | **Coefficient of linear expansion** = elongation in the unit length of a body (1 m) for an increase in temperature by 1 K (= 1° C) | |
| $E$ | **Modulus of elasticity** = ratio of stress $\sigma$ to strain $\varepsilon$ in the case of loaded materials ($E = \sigma / \varepsilon$) or strain factor in Hooke's Law ($\sigma = \varepsilon \cdot E$). | |
| $C$ | **Specific heat** = quantum of heat required to heat 1 g of material by 1 K. | |
| | **Melting point** = temperature at which the material starts melting (only homogenous materials have one melting point in contrast to a range of fusion). | |
| | **Latent heat of fusion** = quantum of heat necessary to convert 1 g of material from a solid to a liquid state at the melting point temperature (the same quantum of heat is released in solidification of the material). | |
|   | **Thermal conductivity** = quantum of heat (W = J/s), which flows in 1 s through an area of material to another surface spaced at a distance of 1 m with a difference of temperature of 1 K. | |
| $\Omega$ | **Specific electrical resistance** = resistance of a conductor with a cross-sectional area of 1 mm² and a length of 1 mm in Ohm ($\Omega$). | |
| | **Boiling point** = temperature at which the material starts evaporated (Transformation form a liquid to a gaseous state). | |
| | **Latent heat of vaporization** = quantum of heat J required to evaporate a mass of 1 g of material at constant boiling point | |
| $H_u$ | **Calorific value** = quantum of heat (kJ) available from the complete combustion of 1 kg mass of material | DIN 5499 (Jan. 72) |
| $\gamma$ | **Coefficient of volumetric thermal expansion.** = expansion in unit volume of a material with increase in temperature by 1 K (= 1° C), for solid materials $\gamma = 3\ \alpha$ is applicable. | |

## Physical properties of pure metals

| Material (element) | Modulus of elasticity $E$ kN / mm² | Specific heat (20 - 100°C) J / gK | Latent heat of fusion J / g | Thermal conductivity, $\lambda$ (°C) W/mK | Specific electrical resistance, $\Omega$ mm²/m | Boiling point °C | Symbol |
|---|---|---|---|---|---|---|---|
| Aluminium | 72 | 0.869 | 397 | 231 | 0.0265 | ≈2500 | Al |
| Antimony | 80 | 0.21 | 165 | 231 | 0.386 | 1635 | Sb |
| Lead | 20 | 0.128 | 24 | 35.3 | 0.21 | 1750 | Pb |
| Cadmium | 51 | 0.233 | 57 | 96.2 | 0.0724 | 767 | Cd |
| Calcium | 23 | 0.68 | 329 | | 0.040 | 1492 | Ca |
| Chromium | | 0.44 | 294 | | 0.150 | ≈2500 | Cr |
| Iron | ≈210 | 0.47 | 269 | 72.3 | 0.100 | 3070 | Fe |
| Gold | 79 | 0.13 | 67 | 310 | 0.0206 | 2950 | Au |
| Iridium | 538 | 0.134 | | 58.5 | 0.493 | 4527 | Ir |
| Cobalt | 215 | 0.427 | 273 | 68.6 | 0.056 | 3185 | Co |
| Copper | 125 | 0.385 | 212 | 395 | 0.0172 | 2595 | Cu |
| Magnesium | 29 | 0.102 | 208 | 143 | 0.043 | 1105 | Mg |
| Manganese | | 0.486 | 271 | 50 | 0.39 | 2041 | Mn |
| Molybdenum | 326 | 0.247 | 288 | 142 | 0.050 | 5550 | Mo |
| Sodium | | 1.165 | 115 | 138 | 0.043 | 881 | Na |
| Nickel | 193 | | 302 | 92.2 | 0.069 | 2730 | Ni |
| Osmium | 570 | 0.131 | 147 | | 0.095 | 4400 | Os |
| Platinum | | 0.135 | 101 | 71.2 | 0.0981 | ≈3800 | Pt |
| Mercury | | 0.139 | 12 | 8.05 | 0.9407 | 356.6 | Hg |
| Selenium | | 0.377 | 83 | | | 68.5 | Se |
| Silver | 82 | 0.234 | 106 | 410 | 0.0149 | 2177 | Ag |
| Silicium | 115 | 0.71 | 1665 | | 1000 | 2600 | Si |
| Tantulum | 188 | 0.138 | | 54.5 | 0.14 | 4100 | Ta |
| Titanium | | 0.616 | | | 0.42 | 3260 | Ti |
| Uranium | | 0.106 | | 29.85 | 0.21 | ≈3500 | U |
| Vanadium | | 0.487 | | | | 3000 | V |
| Bismuth | 33 | 0.125 | 53 | 8.3 | 1.11 | 1560 | Bi |
| Tungsten | 415 | 0.135 | 191 | 162 | 0.05 | ≈6000 | W |
| Zinc | 130 | 0.388 | 96 | 113 | 0.057 | 908.5 | Zn |
| Tin | 55 | 0.227 | 58 | 66 | 0.115 | 2507 | Sn |

## Physical properties of materials

| Material | Density $\varrho$ g/cm³ | Modulus of elasticity, $E$ kN/mm² | Specific heat (20°C) J/gK | Coefficient of linear thermal expansion, (20...100°C) $\alpha \cdot 10^{-6}$m/mK | Thermal conductivity, $\lambda$ (20°C) W/mK | Specific electrical resistance, $\Omega$ mm²/m |
|---|---|---|---|---|---|---|
| Steel (...0.3% C) | 7.85 | 206 | 0.47 | 12.2 | 54 | 0.11 |
| Steel (...0.4...0.7% C) | 7.85 | 206 | 0.48 | 11.5 | 50 | 0.12 |
| Steel (0.7% 1.2% C) | 7.84 | 206 | 0.49 | 11.0 | 46 | 0.12 |
| × 40 Cr 13 | 7.7 | 220 | 0.46 | 10.5 | 30 | 0.55 |
| × 12 CrNiS 18 8 | 7.9 | 200 | 0.50 | 16.0 | 15 | 0.73 |
| 40 CrMn 5 4 | 7.85 | 206 | 0.46 | 11.3 | 38 | 0.15 |
| 100 CrSi 12 8 | 7.7 | 206 | 0.50 | 12.5 | 19 | 0.65 |
| × 100 Mn 14 | 7.95 | 206 | | 14.0 | 12.5 | 0.83 |
| × 100 Ni36 (Invar) | 8.13 | 148 | 0.50 | 1.5 | 12.5 | 0.75 |
| GG-15 | 7.2 | 118... | 0.335 | 11.0 | 58 | 0.8 |
| GG-30 | 7.3 | 128 | 0.46 | 10.0 | 54 | 1.4 |
| GGG-50 | 7.5 | 172 | 0.46 | 11.0 | 29 | 0.6 |
| GTS-55 | 7.4 | 172 | 0.46 | 11.0 | 67 | 0.3 |
| Brass (85% Cu) | 8.73 | 122 | 0.39 | 17.7 | 155 | 0.05 |
| Brass (60% Cu) | 8.40 | 108 | 0.39 | 18.5 | 113 | 0.07 |
| CuZn 40 Al 2 | 8.3 | 102 | 0.40 | 18.5 | 54 | 0.12 |
| G-CuSn 10 | 8.8 | 113 | | 17.0 | 71 | 0.11 |
| Constantan (CuNi 44) | 8.9 | 165 | | 13.5 | 23 | 0.49 |
| Monel (67% Ni, 31% Cu) | 8.9 | 180 | 0.42 | 14.2 | 25 | 0.48 |
| AlCuMg 2 | 2.8 | 70 | 0.92 | 22.8 | 160 | 0.05 |
| AlMgSi 1 | 2.7 | 70 | 0.92 | 23.1 | 175 | 0.04 |
| AlMg 5 | 2.6 | 68 | 0.92 | 23.5 | 117 | 0.055 |
| G-AlSi 12 | 2.65 | 75 | 0.88 | 20.5 | 160 | 0.048 |
| MgMn 2 | 1.8 | 44 | 1.05 | 24.0 | 142 | 0.06 |
| MgAl 8 Zn | 1.8 | 43 | 1.05 | 24.0 | 75 | 0.14 |
| G-MgAl 9 Zn 1 ho | 1.8 | 43 | 1.05 | 24.5 | 71 | 0.15 |

## Thermal properties of liquids

| Liquid | Coefficient of volumetric expansion $\gamma$ (20°C) $10^{-3}$ m³/m³ K | Specific heat $c$ (20°C) J/gK | Melting point °C | Latent of fusion J/g | Boiling point °C | Latent heat of vaporization J/g | Thermal conductivity $\lambda$ (20°C) W/mK |
|---|---|---|---|---|---|---|---|
| Aceton | 143 | 2.16 | − 94.3 | 96 | 56.1 | 523 | 0.161 |
| Formic acid | 102 | 2.18 | + 8.4 | 278 | 100.7 | 495 | |
| Aniline | 85 | 2.06 | − 6.2 | 114 | 184 | 448 | 0.172 |
| Ethyl alcohol | 110 | 2.47 | − 114.5 | 105 | 78.3 | 842 | 0.181 |
| Benzine | 106 | 1.74 | + 5.5 | 127 | 80.1 | 840 | 0.148 |
| Bromine | 113 | 0.46 | − 7.3 | 68 | 58.8 | 180 | |
| Chloroform | 128 | 0.97 | − 63.5 | 79.6 | 61.2 | 247 | 0.118 |
| Acetic acid | 107 | 2.03 | + 16.7 | 195 | 118 | 405 | 0.198 |
| Glycerine | 50 | 2.43 | + 18 | 210 | 290 | | 0.285 |
| Methyl alcohol | 119 | 2.47 | − 98 | 101 | 64.5 | 1100 | 0.205 |
| Nitro benzene | 83 | 1.51 | + 5.7 | 98 | 211 | 397 | |
| Nitric acid | 124 | 1.72 | − 41 | 39.8 | 86 | 482 | |
| Carbon disulphide | 119 | 1.02 | − 112 | 74 | 46.3 | 372 | |
| Sulphuric acid | 57 | 1.39 | + 10.5 | 109 | | | |
| Terpentine oil | 97 | 1.80 | − 10 | | 160 | 293 | |
| Toluene | 108 | 1.68 | − 95 | 72 | 110.7 | 355 | |
| Water | 18 | 4.18 | 0.0 | 334 | 100 | 2260 | 0.598 |

## Thermal properties of gases

| Gas | Symbol | Density of gas $\varrho$ (0°C) kg/m³ | Boiling point °C | Specific heat capacity $c_q$ (0°C) J/gK | Latent heat of evaporization J/g | Density of liquid (at boiling point) kg/dm³ |
|---|---|---|---|---|---|---|
| Ammonia | $NH_3$ | 0.7714 | − 33.4 | 2.06 | 1370 | 0.680 |
| Argon | Ar | 1.7839 | − 185.9 | 0.52 | 157 | 1.404 |
| Acytene | $C_2H_2$ | 1.1709 | − 83.6 | 1.64 | 830 | 0.613 |
| Chlorine | $Cl_2$ | 3.22 | − 35.0 | 0.50 | 260 | 1.558 |
| Hydrochlorid acid | H Cl | 1.6391 | − 85 | 0.81 | 444 | |
| Helium | He | 0.1785 | − 268.9 | 5.23 | 21 | 0.125 |
| Carbon dioxide | $CO_2$ | 1.9768 | − 78.5 | 0.83 | 574 | |
| Carbon monoxide | CO | 1.2500 | − 191.5 | 1.05 | 216 | 0.801 |
| Krypton | Kr | 3.74 | − 153.2 | | 117 | |
| Air | - | 1.2928 | − 194.0 | 1.00 | 197 | 0.875 |
| Methane | $CH_4$ | 0.7168 | − 161.7 | 2.18 | 506 | 0.415 |
| Methylchloride | $CH_2Cl$ | 2.307 | − 24.0 | 0.74 | 417 | 0.997 |
| Neon | Ne | 0.9 | − 246 | 1.03 | 105 | 1.207 |
| Propane | $C_3H_3$ | 2.02 | − 42.6 | | 427 | 0.585 |
| Oxygen | $O_2$ | 1.429 | − 183 | 0.91 | 213 | 1.131 |
| Sulpher dioxide | $SO_2$ | 2.926 | − 10.0 | 0.63 | 400 | 1.460 |
| Hydrogen sulphide | $H_2S$ | 1.539 | − 60.4 | 1.11 | 548 | 0.92 |
| Nitrogen | $N_2$ | 1.25 | − 195.8 | 1.04 | 200 | 0.810 |
| Hydrogen | $H_2$ | 0.0899 | − 253 | 14.25 | 454 | 0.071 |

# Specific calorific value of combustible material

| Solid combustible material | Specific calorific value, kJ / kg | Liquid & gaseous combustible material | Specific calorific value, kJ / kg |
|---|---|---|---|
| Anthracite coal | 31400 | Ethyl alcohol | 27000 |
| Non-bituminous coal | 30800 | Spirit (95%-wt.) | 25300 |
| Rich coal | 31400 | Spirit (85‰-wt.) | 22400 |
| Raw lignite | 12000 | Benzene (pure) | 40000 |
| Lignite dust | 21140 | Toluene | 40800 |
| Coke | 28500 | Benzene – grade I | 40000 |
| Mine coke | 30000 | Benzene – grade II | 40500 |
| Hard coal-low temp. carboniz. | 23500 | Naphthalene | 38000 |
| Lignite avg. | 20000 | n – Octane | 44500 |
| Hard coal-briquette avg. | 32000 | Benezene | 42700 |
| Lignite-briquette | 20500 | Petroleum | 44000 |
| Beech wood | 20000 | Coal tar avg. | 35500 |
| Oak wood | 19500 | Hard coal – leary oil | 38000 |
| Ash wood | 20000 | Lignite tar | 36800 |
| Spruce wood avg. | 21400 | Paraffin oil | 41000 |
| Elm wood | 20000 | Acetylene | 54500 |
| Charcoal | 33500 | Producer gas | 6300 |
| Sawdust | 13800 | Carbon monoxide | 10000 |
| Peat (dry) avg. | 11700 | Coal gas | 17600 |

# Acids, alkalies and alcohols in various concentrations

Density in g / cm³ at 15 °C

| Content in weight % | | 1 | 5 | 10 | 20 | 30 | 40 |
|---|---|---|---|---|---|---|---|
| Hydrochlorid acid | HCl | 1.0032 | 1.0230 | 1.0474 | 1.0980 | 1.1493 | 1.1980 |
| Sulphuric acid | $H_2SO_4$ | 1.0051 | 1.0317 | 1.0661 | 1.1394 | 1.2158 | 1.3028 |
| Nitric acid | $HNO_3$ | 1.0036 | 1.0256 | 1.0543 | 1.1150 | 1.1800 | 1.2463 |
| Phosphoric acid | $H_3PO_4$ | 1.0038 | 1.0250 | 1.0532 | 1.1134 | 1.1805 | 1.2540 |
| Acetic acid | $CH_3COOH$ | 0.9996 | 1.0055 | 1.0125 | 1.0263 | 1.0384 | 1.0488 |
| Ammonia | $NH_3$ | 0.996 | 0.979 | 0.960 | 0.925 | 0.895 | |
| Sodium hydroxide | NaOH | 1.011 | 1.055 | 1.111 | 1.221 | 1.331 | 1.434 |
| Potassium hydroxide | KOH | 1.008 | 1.045 | 1.094 | 1.188 | 1.291 | 1.399 |
| Methyl alcohol | $CH_3OH$ | 0.9973 | 0.9905 | 0.9826 | 0.9681 | 0.9536 | 0.9370 |
| Ethyl alcohol | $C_2H_5OH$ | 0.9973 | 0.9903 | 0.9831 | 0.9708 | 0.9569 | 0.9389 |

| Content in weight % | | 50 | 60 | 70 | 80 | 90 | 100 |
|---|---|---|---|---|---|---|---|
| Sulphuric acid | $H_2SO_4$ | 1.3956 | 1.4983 | 1.6105 | 1.7272 | 1.8144 | 1.8305 |
| Nitric acid | $HNO_3$ | 1.3100 | 1.3667 | 1.4137 | 1.5221 | 1.4826 | 1.5129 |
| Phosphoric acid | $H_3PO_4$ | 1.355 | 1.426 | 1.526 | 1.633 | 1.746 | 1.870 |
| Acetic acid | $CH_3COOH$ | 1.0575 | 1.0642 | 1.0685 | 1.0700 | 1.0661 | 1.0498 |
| Methyl alcohol | $CH_3OH$ | 0.9186 | 0.8979 | 0.8749 | 0.8504 | 0.8239 | 0.7959 |
| Ethyl alcohol | $C_2H_5OH$ | 0.9179 | 0.8953 | 0.8719 | 0.8478 | 0.8223 | 0.7936 |

# Chemical names and formulae of few materials

| Trade name | Chemical name | Chemical formula | Trade name | Chemical name | Chemical formula |
|---|---|---|---|---|---|
| Acetone | Acetone | $C_3H_6O$ | Copper vitrol | Copper sulphate | $CuSO_4+5H_2O$ |
| Acetylene | Acetylene | $C_2H_2$ | Soldering salt | Chlorine zinc ammoniac | $ZnCl_2+2NH_4Cl$ |
| Benzene | Carbon hydride | $C_6H_6$ | Lead oxyde (red) | High lead oxide | $Pb_4O_4$ |
| White lead | Lead hydrocarbon | $2PbCo_3Pb(OH)$ | Polarisation red | Ferrous oxide | $Fe_2O_6$ |
| Red alkaline salt | Potasium-iron-5 cyanide | $K_3Fe(CN)_6+3H_2O$ | Propane gas | Propane gas | $C_3H_8$ |
| Borax | Sodium tetraborate | $Na_2B_4O_7+10H_2O$ | Rust | Ferrous hydroxide | $Fe(OH)_3$ |
| Potassium cyan. | Potassium cyanide | KCN | Ammonium chloride | Ammonium chloride | $NH_4Cl$ |
| Chips green | Copper acetate | $Cu_2CH(COO)_2+5H_2O$ | Hydrochloric acid | Hydrogen chloride | HCl, in water |
| Carbide | Calcium carbide | $CaC_2$ | Sulphuric acid | Sulphuric acid | $H_2SO_4$ |
| Edible salt | Sodium chloride | NaCl | Sodium Sodo | Sodium carbonate | $Na_2CO_3$ |
| Corundum | Aluminiumoxide | $Al_2O_3$ | Water | Water | $H_2O$ |
| | | | Zinc white | Zinc oxide | ZnO |
| | | | Tin ash | Stannic oxide | $SnO_2$ |

# System of naming iron and steel

DIN 17006 (Oct. 49)

## Steel

**Plain steel**: < 0.5 % Silicon; < 0.8 % Manganese; < 0.1 % Aluminium or Titanium; < 0.25 % or copper

**Alloy steel**: > 0.5 %; > 0.8 %; > 0.1 %; > 0.25 %

| Steels not subjected to heat treatment (structural steel) | Steels subjected to heat treatment (tough steel) | Plain tool steels | Low alloy steels with < 5 % specific alloying elements | High alloy steels with > 5 % specific alloying elements |
|---|---|---|---|---|
| The system of naming is as follows | | | | |
| 1. Symbol **St**<br>2. Minimum tensile strength in N / mm² | 1. Symbol **C** for carbon<br>2. Index for carbon content | 1.<br>2. Symbol W 3. | Symbol **X** 1.<br>1. Index for carbon content 2.<br>2. Symbol for alloying element 3.<br>3. Indices for element alloying 4. | |
| e. g. | | | | |
| **St 42** | **C 35** | **C 100 W 2** | **15 Cr 3** | **X 10 Cr Ni 188** |
| Steel having a tensile strength of 410 N / mm² | Carbon steel with 0.35 % C | Tool steel with 1.00 % C, 2nd grade | Chrom steel with 0.15 % C, 0.75 % Cr | Nickel-Chromium steel 0.10 % C, 18 % Cr, 8 % Ni. |
| | 1) | 1) | 1) | |
| Applicable for steel as per DIN 1611 1612 1613 1621 1622 1628 1629 1652 | Fine steels with low content of S and P has the addition k, e. g. Ck 35 | W 1 = 1st grade<br>W 2 = 2nd grade<br>W 3 = 3rd grade<br>WS = for specific purpose | The alloying constituents are systematized with the decreasing order of %-content | For high alloy steel or cast iron: C-content in hundredth, alloying constituents in their full percentage value |

## Castings

System of naming **plane** castings

1. Symbol for castings
2. Tensile strength

or

1. Cast sign
2. Symbol C
3. C-content in hundredth

System of naming **alloying** castings

1. Symbol for casting
2. C-content upto 100th place
3. Symbols for alloying additives in **high alloy** casting:
1. Alphabet X + 1, 2, 3, 4

| GS- Cast steel | CG- Grey cast iron | GH- (Hard) cast iron | GT- Malleable cast iron |
|---|---|---|---|
| GS-52 Cast steel with tensile strength of 510 N / mm² | GG-18 Grey cast iron with a tensile strength of 180 N/mm² | GH-25 Chill (Hard) cast iron with a 25 mm depth | GTW-35 White malleable cast iron with tensile strength of 340 N / mm² |
| GS-C25 Cast steel with 0.25 % C | GGK Chilled grey iron casting | GH-95 ... with 95° shore hardness. It means a number upto 50: a hardness depth above 50: a shore hardness | GTS-35 Black mall. iron with tens. strength 330 N / mm² |
| GS-55 Cr6 Alloy with 0.55% C and 1,5 % Cr. 1) | GGZ Spin grey Iron Z = spin casting (centrifugal moulding) | | GTW-S 40 White malleable cast iron with tensile strength 390 N / mm² |

1) In order to maintain the correct percentage, the index number of the alloy additives must be divided for low alloy materials by:
4 in case of Co Cr Mn Ni Si W
10 in case of Al Be B Cu Mo Nb Pb Ta Ti V Zr
100 in case of C Ce N P S

Theoretically, the following individual symbols in sequence serve to get full nomenclature: 1. Casting symbol with hyphen 2. Symbols for smelting technique (steel type) 3. Symbols on properties which are decided by smelting or processing technique. 4. X classifies high alloy material 5. Symbol C (or St) 6. C index number (or tensile strength) 7. Symbols of alloying elements. 8. Alloying index number 9.1 The index figure denoting the full guarantee or 9.2. W. 1 etc. for plain tool steel 10. Symbols denoting the state of processing. 11. Minimum tensile strength or an other property which should be obtained by processing 12. Characteristic symbols for surface quality.

| The essence of this nomenclature | is for | 5( )+6( ) plain steel | 1+6( ) alloy casting | (4)6+7+8 alloy steel | (4)1+6+7+8 alloy casting |
|---|---|---|---|---|---|

## Smelting process

B = Bessemer Steel
E = Electrosteel
F = Open hearth furnace
I = Electrosteel (induction)
LE = Electrosteel (arc)
M = SM steel
PP = Puddled steel
SS = Welding steel
T = Thomas steel
Ti = Crucible (cast) steel
W = Purified furnace steel

**Examples**

GS-B40 Bessemer cast steel with 390 N / mm² tensile strength
TSt 37 Thomas steel with tensile strength of 360 N / mm²
S St 37 360 N / mm² smelt-weldable

## Additional symbols denoting special properties

A = Non-ageing quality
G = Greater P-or S-content
H = Semi-killed
K = Smaller P-or S-content
L = Alkali resistive
P = Suitable for press. welding
Q = Cold workable
R = Killed
S = Suitable for fusion welding
U = Unkilled
Z = Ductile

GS-BS 40 Suitable for fusion welding. Bessemer cast steel with tensile strength of 390 N / mm²

ASt 42N Non-ageing steel with 410 N / mm² tensile strength normalized

## Treatment given

A = Tempered
B = Best workability
E = Case hardened
G = Soft annealed
H = Hardened
K = Cold worked
HF = Surface hard. by flame
HI = Surface hard. by induction
N = Normalized
NT = Nitrated
S = Stress relieved
U = Untreated
H = Hardened and tempered

15Cr 3E Chromium steel 0.15% C & 0.75% Cr, case hardened

C 100 W 2G Tool steel, 2nd grade 1% C, soft annealed

| Symbols | Tensile strength N / mm² | Bending strength N / mm² | Density kg / dm³ | **Cast iron with graphite laminations** Properties and application | DIN 1691 (Aug. 64) still suppl. as |
|---|---|---|---|---|---|
| **GG-10** | 100 | – | 7.2 | Normal cast steel without any special quality, for normal use | GG-12 |
| **GG-20** | 200 | 350 | | | GG-14 |
| **GG-25** | 250 | 420 | 7.35 | Good quality cast iron for parts subjected to severe loading e. g. cylinders, pistons | GG-18 |
| **GG-35** | 340 | 530 | | | GG-21 |
| **GG-40** | 390 | 590 | | | GG-26 |

| Symbols | Tensile strength N / mm² | 0.2[1] Limit. stress N / mm² | Breaking strain (%) ($l_o = 5\,d_o$) | **Nodular graphite cast iron** Workability | Properties | DIN 1693 (Oct. 73) |
|---|---|---|---|---|---|---|
| **GGG-40** | 400 | 250 | 15 | Good | Due to carbon as graphite in modular form. GGG has similiar properties to steel | |
| **GGG-50** | 500 | 320 | 7 | Very good | | |
| **GGG-60** | 600 | 380 | 3 | Very good | | |
| **GGG-70** | 700 | 440 | 2 | Good | | |

| Symbols | Tensile strength N / mm² | 0.2[1] Limit. stress N / mm² | Breaking strain (%) ($l_o = 3\,d_o$) | **Malleable iron** Properties | Use | DIN 1692 (June 63) |
|---|---|---|---|---|---|---|
| **GTW-40** | 390 | 215 | 5 | High grade white malleable iron | Thin walled tough castings e. g. wheels, keys, fittings | |
| **GTW-55** | 540 | 355 | 5 | | | |
| **GTS-45** | 440 | 295 | 7 | High grade | | |

| Symbols | Tensile strength N / mm² | Yield strength N / mm² | Breaking strain (%) ($l_o = 5\,d_o$) | **Cast steel** Properties | Use | DIN 1681 (June 63) |
|---|---|---|---|---|---|---|
| **GS-38** | 370 | 185 | 25 | Standard quality very tough, ductile | Used instead of grey cast iron if greater strength or toughness is required | |
| **GS-45** | 440 | 225 | 22 | | | |
| **GS-60** | 590 | 295 | 15 | Much compact, less ductile | | |
| **GS-70** | 690 | 410 | 12 | | | |

| Symbols | Tensile strength N / mm² | Breaking strain (%) ($l_o = 5\,d_o$) | **Ferritic cast steel for high temperature** 0.2-limiting value at temperatures of (° C) 20 | 200 | 300 | 400 | 500 | Use | DIN 17245 (July 67) |
|---|---|---|---|---|---|---|---|---|---|
| **GS-C 22** | 440...590 | 22 | 245 | 190 | 167 | 137 | – | Cast parts for operating temperatures between 300° C and 600° C | |
| **GS-22 Mo4** | 440...590 | 22 | 245 | 206 | 190 | 162 | 147 | | |
| **GS-17 CrMo5 5** | 490...640 | 20 | 315 | 260 | 235 | 206 | 182 | | |
| **G-X22 Cr Mo V 12 1** | 690...880 | 15 | 590 | 530 | 485 | 412 | 324 | | |

[1] 0.2-limit at the yield point: tension in N / mm² for a constant elongation of 0.2% of the original length.

# Quality standard

## General structural steels

DIN 17100 (Sept. 66)

| Steel types | Similar steel types as per Eurostandard 25 | Minimum Tensile strength $N/mm^2$ | Minimum Yield point $N/mm^2$ | Breaking strain $5\,d_o$ % | C % | Suitability for fusion welding | Suitability for folding | Suitability for impact forging |
|---|---|---|---|---|---|---|---|---|
| **St 33-1** | Fe 33-0 | 320 | 185 | 18 | – | Low | – | – |
| **St 33-2** | – | | | | – | Suitable | – | – |
| **St 34-1** | Fe 34-A | 320 | 205 | 28 | 0.17 | Suitable | – | P St 34-1 |
| **St 34-2** | Fe 34-B3 FU | | | | 0.15 | Suitable | Q St 34-2 | P St 34-2 |
| **St 37-1** | Fe 37-A | 360 | 235 | 25 | 0.20 | Suitable | – | P St 37-1 |
| **St 37-2** | Fe 37-B3 FN | | | | 0.18 | Suitable | Q St 37-2 | P St 37-2 |
| **St 37-3** | Fe 37-C3 | | | | 0.17 | Suitable | Q St 37-3 | – |
| **St 42-1** | Fe 42-A | 410 | 255 | 22 | 0.25 | Low | – | – |
| **St 42-2** | Fe 42-B3 FN | | | | 0.25 | Suitable | Q St 42-2 | P St 42-2 |
| **St 42-3** | Fe 42-C3 | | | | 0.23 | Suitable | Q St 42-3 | – |
| **R St 46-2** | – | 430 | 285 | 22 | 0.20 | Suitable | Q St 46-2 | – |
| **St 46-3** | – | | | | 0.20 | Suitable | – | – |
| **St 52-3** | Fe 52-D3 | 510 | 355 | 22 | 0.20 | Suitable | Q St 52-3 | P St 52-3 |
| **St 50-2** | Fe 50-2 | 490 | 295 | 20 | ≈ 0.30 | Low | – | P St 50-2 |
| **St 60-1** | Fe 60-1 | 590 | 335 | 15 | ≈ 0.35 | – | – | – |
| **St 70-2** | Fe 70-2 | 690 | 365 | 10 | ≈ 0.50 | – | – | – |

Grade 1 steel - for general use, Grade 2 - steel for high demand, grade 3 - steel for special purposes.

Standard sizes for hot-rolled products made from general structural steels:

| DIN | Characterization | DIN | Characterization | DIN | Characterization | DIN | Characterization |
|---|---|---|---|---|---|---|---|
| 1013 | ⌀-Steel | 1018 | ⌓-Steel | 1024 | T-Steel | 1029 | L-Steel of unequal sizes |
| 1014 | □-Steel | 1019 | Flat bulb steel | 1025 | I-Steel | 1542 | Sheet metal 3...4.75 mm |
| 1015 | ○-Steel | 1022 | Sharp-edged L angle steel | 1026 | U-Steel | 1543 | Sheet met.w. 5 mm a. more |
| 1016 | Strip steel | | | 1027 | Z-Steel | 59200 | Wide-flat steel |
| 1017 | Flat steel | | | 1028 | L-Round-edged-steel | 59051 | T-steel sharp-edged |

The material characterization is added to the standard designation e.g. I 200 x 5000 DIN 1025 St 37

## Case hardened steels

DIN 17210 (Dec. 69)

| Steel types Short name | Similar steel types as per Eurostandard 84 | Average C-content % | on blank hardened section of 30 mm Ø: [1] Tensile strength $N/mm^2$ | Yield point $N/mm^2$ | Break. strain (%) $(l_o = 5\,d_o)$ | Use |
|---|---|---|---|---|---|---|
| **C 10; Ck 10** | 2 C 10 | 0.10 | 490... 640 | 295 | 16 | For the machine parts having tough cores and hardened surfaces e.g. levers, pins, tappets, measuring tools, shafts |
| **C 15; Ck 15** | 2 C 15 | 0.15 | 590... 780 | 345 | 14 | |
| **15 Cr 3** | 15 Cr 2 | 0.15 | 690... 880 | 440 | 11 | |
| **16 MnCr 5** | 16 MnCr 5 | 0.16 | 780...1080 | 590 | 10 | |
| **20 MnCr 5** | – | 0.20 | 980...1270 | 685 | 8 | |
| **15 CrNi 6** | 14 CrNi 6 | 0.15 | 880...1180 | 635 | 9 | |
| **18 CrNi 8** | 13 NiCr 12 | 0.18 | 1180...1420 | 785 | 7 | |

## Tempering steels

DIN 17200 (Dec. 69)

| Steel types Short name | Similar steel types as per Eurostandard 83 | Average C-content % | in the tempered state of 16 to 40 mm Ø: Tensile strength $N/mm^2$ | Yield point $N/mm^2$ | Break. strain (%) $(l_o = 5\,d_o)$ | Use |
|---|---|---|---|---|---|---|
| **C 35; Ck 35** | 1 C 35 | 0.35 | 580... 730 | 365 | 19 | Toothed-wheel work shafts, springs, axils, toothed-cutter crankshafts for medium and high loads |
| **C 45; Ck 45** | 1 C 45 | 0.46 | 660... 800 | 410 | 16 | |
| **C 60; Ck 60** | 1 C 60 | 0.61 | 780... 930 | 490 | 13 | |
| **28 Mn 6** | 28 Mn 6 | 0.28 | 690... 830 | 490 | 15 | |
| **38 Cr 2** | 38 Cr 2 | 0.38 | 690... 830 | 440 | 15 | |
| **34 Cr 4** | 34 Cr 4 | 0.34 | 780... 930 | 590 | 14 | |
| **25 CrMo 4** | A 25 CrMo 4 | 0.25 | 780... 930 | 590 | 14 | |
| **32 CrMo 12** | 32 CrMo 12 | 0.32 | 1230...1420 | 1030 | 9 | |

[1] Blank-hardened, i. e. quenched at 860 to 910° C

## Steels with ageing resistance

DIN 17135 (March 64)

| Short name | C content % | Tensile strength N/mm² | Breaking strain $l_o=5\,d_o$ % | Yielding point at ... °C N/mm² 20 | 200 | 250 | 300 | 350 | Al % | Si % | Mn % | Cr % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ASt 35** | 0.17 | 340...440 | 25 | 205 | 177 | 167 | 137 | 118 | | 0.35 | 0.40 | |
| **ASt 41** | 0.20 | 400...490 | 22 | 235 | 206 | 186 | 157 | 137 | above | 0.35 | 0.45 | below |
| **ASt 45** | 0.22 | 440...540 | 21 | 255 | 226 | 206 | 177 | 157 | 0.02 | 0.35 | 0.45 | 0.3 |
| **ASt 52** | 0.20 | 510...610 | 22 | 335 | — | — | — | — | | 0.55 | 1.50 | |

The Standard 17135 applies to medium and coarse sheet metal, wide flat steel, seamless tubes, har steels, strap steel.

## Thin sheets

### Thin sheets made of soft steels

DIN 1623 Pg.1 (No. 72)

| Symbol | C-content % | Tensile strength N/mm2 | Breaking Strain $l_o=80$ $b_o=20$ % | Yield point N / mm² | Quality | Use |
|---|---|---|---|---|---|---|
| **USt 12** | 0.10 | 270...410 | 28 | 280 | Drawing quality | The refinement of surfaces and reshapings |
| **USt 13** | 0.10 | 270...370 | 32 | 250 | Deep drawing quality | |
| **USt 14** | 0.08 | 270...350 | 36 | 220 | Extra-deep quality | |

### Thin sheets made of plain steels

DIN 1623 Pg. 2 (Jan. 61)

| | | | | | | |
|---|---|---|---|---|---|---|
| **TUSt 37 USt 37-2** | 0.20 | 360...440 | 18 | 215 | Melting point; and can be rolled, welded and drawn. | Due to tensile strength and yield point supplied as black, galvanized-, enameled body sheets |
| **RSt 42-2** | 0.25 | 410...490 | 16 | 235 | | |
| **St 50-2** | 0.30 | 490...590 | 14 | 295 | Bending strength-R R=thickness of sheet | |
| **St 52-3** | 0.20 | 510...610 | 16 | 355 | Suitable for fusion welding | |
| **St 60-2** | 0.40 | 590...690 | 10 | 335 | — | |
| **St 70-2** | 0.50 | 690...830 | 6 | 365 | — | |

## Characterization of surface-finishes and surface-performance

DIN 1623 (Nov. 72)

| Code | Surface finish | Remarks |
|---|---|---|
| (02 | Normal annealed, scale not removed | Tempering and annealing colours and loose scale tolerated |
| 03 | Free of scale | Pores, minute pits and rolling marks tolerated |
| (04 | Improved finish | Pores, minute pits and rolling marks along the periphery tolerated) |
| 05 | Best finish | Pores, pits and marks must not impair the quality of spray painted finish |
| | Surface performance | |
| g | smooth | The finish must appear evenly glossy |
| m | faint | The finish must appear evenly faint |
| r | rough | The finish is intentionally made rough |

Standard DIN 1541

Designations:

**RR St 14 05 m** — special stabilized (RR), fine sheets of the extra deep stretching quality (St 14) with the best faint surfaces finish (05 m)

**TUSt 37 02** — thin sheet made of Thomas steel St 37 (TUSt 37), scale not removed (02)

**St 52 – 3 03** — thin sheet steel of St 52 quality group 3 (St 52-3) scale removed surface finish (03)

1) Material for medium (3-4.75 mm) and large sheets (above 4.75 mm) as per DIN 17100

## Spring steel

**Hot formed spring steel** — DIN 17 221 (Dec. 72)

| Steel quality short name | Comparable to Eurostandard 89/717 | Tensile strength N/mm² | Breaking strain % [1] | Heat-treated: yielding point N/mm² | Use |
|---|---|---|---|---|---|
| Good quality steel | | | | | |
| 38 Si 7 | 50 Si 7 | 1180...1370 | 6 | 1030 | In annealed state for leaf, torquerods, screws and plate springs as well as for spring rings and springing parts of all kinds |
| 51 Si 7 | | 1320...1570 | 6 | 1130 | |
| 60 SiCr 7 | | 1320...1570 | 6 | 1130 | |
| 55 Cr 3 | 55 Cr 3 | 1370...1620 | 6 | 1180 | |
| 50 CrV 4 | 50 CrV 4 | 1370...1670 | 6 | 1180 | |
| 51 CrMoV 4 | 51 CrMoV 4 | 1370...1670 | 6 | 1180 | |

**Cold rolled steel stripes for springs** — DIN 17 222 (Apr. 55)

| Soft annealed | Tensile strength N/mm² | Good quality steel | | | | |
|---|---|---|---|---|---|---|
| C 53 | 590 | 1180...1420 | 6 | 1030 | Manufacture of springing parts and all kinds of springs: hardening and tempering according to the shape | |
| C 75 | 640 | 1180...1570 | 6 | 1080 | | |
| 60 SiMn 5 | 830 | 1670...2160 | 5 | 1570 | | |
| Refined steel | | | | | | |
| Ck 67 | 640 | 1370...1620 | 6 | 1275 | | |
| 71 Si 7 | 830 | 1860...2360 | 4 | 1765 | | |
| 50 CrV 4 | 780 | 1670...2260 | 5 | 1576 | | |

**High temperature steel for springs** — DIN 17 225 (Apr. 55)

| Code | Tensile strength N/mm² (20 °C) | Yielding point at ... °C N/mm² 100 | 200 | 300 | 400 | upto °C | Use |
|---|---|---|---|---|---|---|---|
| 45 CrMoV 6 7 | 1370...1670 | 1030 | 932 | 834 | 686 | 450 | Manufacture of springs and springing parts for use at temperatures above 250 °C. |
| 30 WCrV 17 9 | 1370...1670 | 1079 | 981 | 883 | 735 | 500 | |
| 65 WMo 34 8 | 1370...1670 | 1079 | 981 | 883 | 785 | 550 | |

## Screw steel

**High temperature steels for nuts and bolts** — DIN 17 240 (Jan. 59)

| Short name | Tensile strength N/mm² (20 °C) | Breaking value of [1] (20 °C) % | Yielding point at ... °C N/mm² 20 | 200 | 300 | 350 | 400 | 450 | 500 |
|---|---|---|---|---|---|---|---|---|---|
| 24 CrMo 5 | 590...740 | 18 | 440 | 412 | 363 | 333 | 304 | 275 | 235 |
| 24 CrMoV 5 5 | 690...830 | 17 | 540 | 490 | 451 | 431 | 402 | 373 | 343 |
| 21 CrMoV 5 11 | 690...830 | 17 | 540 | 510 | 481 | 461 | 431 | 402 | 373 |

**Drawn steel for cold worked screws** — DIN 1654 (Aug. 54)

| Code | Tensile strength max. [2] N/mm² | For screws | Yield point N/mm² | Breaking strain [1] % | Delivery state Use |
|---|---|---|---|---|---|
| Cq 22 | 640 | 5.6 | 295 | 20 | Cold and mildly annealed (K+G) or K+G+K for cold heading of screws |
| Cq 45 | 690 | 8.8 | 630 | 12 | |
| 41 Cr 4 | 690 | 10.9 | 885 | 9 | |
| 41 CrV 6 | 690 | 12.9 | 1060 | 8 | |

## Boiler plate materials

DIN 17 155 Pg. 2 (March 64)

| Symbol | Tensile strength N/mm² | C-Content % | Yield point at ... °C (Upto 60 mm thickness) N/mm² 20 | 200 | 300 | 400 | 450 | Use |
|---|---|---|---|---|---|---|---|---|
| H I | 340...440 | 0.16 | 205 | 177 | 137 | 98 | 88 | For steam boilers, pressure vessel and pressure pipelines. All steels can be welded by fusion |
| H II | 400...490 | 0.20 | 235 | 206 | 157 | 118 | 98 | |
| H III | 430...520 | 0.22 | 255 | 226 | 177 | 137 | 118 | |
| H IV | 460...550 | 0.26 | 265 | 235 | 186 | 147 | 127 | |
| 17 Mn 4 | 460...550 | 0.17 | 275 | 245 | 206 | 157 | 137 | |
| 13 CrMo 4 4 | 430...550 | 0.14 | 295 | 275 | 235 | 206 | 196 | |

## Steel pipes

**Seamless from high temperature steels** — DIN 17 175 Pg. 2 (March 64)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| St 35.8 | 340...440 | 0.17 | 235 | 186 | 137 | 108 | 88 | For temperatures upto 580 °C and high pressures. |
| St 45.8 | 440...540 | 0.22 | 255 | 206 | 157 | 127 | 108 | |
| 15 Mo 3 | 440...540 | 0.16 | 285 | 255 | 206 | 177 | 167 | |
| 10 CrMo 9 10 | 440...590 | 0.15 | 265 | 245 | 226 | 206 | 196 | |

**Seamless precision steel pipes** — DIN 2391 Pg. 2 (July 67)

| Symbol | Normalized: Tensile strength N/mm² | Yield point N/mm² | Breaking strain [1] % | Use |
|---|---|---|---|---|
| St 35 | 340...440 | 235 | 25 | BK = bright hard (low formable) BKW = bright soft partly cold formable GBK = annealed (under $O_2$ closure) NBK = normal annealed (under $O_2$ closure) |
| St 55 | 540...640 | 295 | 17 | |
| St 45.2 | 440...540 | 255 | 21 | |
| St 52.2 | 510...610 | 355 | 22 | |

1) Test speciman $l_o = 5\ d_o$ 2) In delivered state, other values for tempered state

## Cold worked steel bands of soft plain steel

DIN 1624 (Aug. 54)

| Steel quality: Code | Steel quality: Nomenclature | State of treatment: Symbol[1] | State of treatment: State | Tensile strength $\sigma$ N/mm² | Breaking strain $l_0 = 5d_0$ minim. % | Chemical composition (0.03 to 0.20 % Si, 0.20 to 0.45 % Mn): C % | P % | S % | Directions on processing | Dim. accord to DIN 1544 (Aug. 54) thickn. |
|---|---|---|---|---|---|---|---|---|---|---|
| St 0 | Basic quality | K | hard | No spec. requirem. without qual. warr. | | 0.12 | 0.08 | 0.06 | | 0,10 |
| | | G | mild. anneal. | | | | | | low degree of deformation | 0.15 |
| | | LG | slightly glossy | | | | | | | 0.20 |
| St 1 | Folding quality | K | hard | No spec.requirem. | | 0.12 | 0.07 | 0.06 | | 0.25 |
| | | G | soft annealed | < 420 | 28 | | | | Moderate degree of deformation | 0.30 |
| | | LG | slightly glossy | < 440 | 26 | | | | | 0.40 |
| | | K 32 | cold rolled | 310...450 | | | | | | 0.50 |
| | | K 40 | | 390...540 | | | | | | 0.60 |
| | | K 50 | | 490...640 | | | | | | 0.80 |
| | | K 60 | | 590...740 | | | | | | 1.0 |
| | | K 70 | | < 690 | | | | | | 1.2 |
| St 2 | Drawing quality | G | soft annealed | 290...390 | 32 | 0.10 | 0.06 | 0.05 | med. degree of deform. | 1.5 |
| | | LG | slightly glossy | 310...410 | 30 | | | | | 1.8 |
| | | K 32 | cold rolled | 310...430 | 24 | | | | | 2.0 |
| | | K 40 | | 390...540 | 14 | | | | | 2.5 |
| | | K 50 | | 490...640 | 5 | | | | | 3,0 |
| | | K 60 | | 590...740 | 2 | | | | | 3.5 |
| | | K 70 | | < 690 | | | | | | 4.0 |
| St 3 | Deep drawing quality | G | soft annealed | 270...370 | 35 | 0.10 | 0.04 | 0.04 | high degr. of deform. | 5.0 |
| | | LG | slightly glossy | 290...390 | 33 | | | | | |
| | | K 32 | cold rolled | 310...410 | 26 | | | | | |
| | | K 40 | | 390...490 | 16 | | | | | |
| St 4 | Extra deep drawing quality | G | soft annealed | 270...370 | 38 | 0.10 | 0.03 | 0.035 | highest degr. of deform. | Breadth of cold treated stripes upto 630 |
| | | LG | slightly glossy | 290...390 | 36 | | | | | |
| | | K 32 | cold rolled | 310...410 | 28 | | | | | |
| | | K 70 | | < 690 | – | | | | | |

Spot weldable with surface finish GBK, RP and RPG

[1] Codes used, correspond roughly with the following codes used previously:
K 32 = 1/8 hard, K 40 = 1/4 hard, K 50 = 1/2 hard, K 60 = 3/4 ... 4/4 hard, K 70 = quality of hard spring

[2] Symbols for surface finish GD = dark annealed, GBK = blank annealed; RP = free of cracks and pores, RPG = free of cracks and pores, bright shining

Designation used to specify a cold worked steel stripe having a stretch quality (St 2), cold re-rolled to a 400 n/mm² tensile strength (K 40), surface bright annealed (GBK): St 2 K 40 GBK
– made of killed Siemens Martin Steel: MR St 2 K 40 GBK

## Low carbon steel for screws, nuts and rivets

DIN 17111 (Jan. 68)

| Symbol | Tensile strength N/mm² | C-content % | Breaking strain % | Yield point N/mm² | Properties and use | |
|---|---|---|---|---|---|---|
| USt 36-1 | 330...430 | 0.14 | 30 | 205 | | not brittle when cold or hot |
| UQSt 36-2 | | 0.13 | | | can be cold headed | |
| USt 38-2 | 370...460 | 0.19 | 25 | 225 | | |
| UQSt 38-2 | | 0.19 | | | can be cold headed | |
| RSt 44-2 | 430...530 | 0.18 | 24 | 255 | | |
| 6P 10 | (340...490) | 0.09 | – | (185) | Earlier referred to as warm pressed steel for nuts | |
| U 10 S 6 | (340...470) | 0.15 | – | (225) | Earlier referred to as cold pressed steel for nuts | |

## Machining steel

DIN 1651 (April 70)

| | | | normalized | | | |
|---|---|---|---|---|---|---|
| 9 S 20 | 360...530 | ≦ 0.13 | 25 | 225 | | Supplied in the following forms: **U** = rolled or forged, **SH** = Shell steel, **N** = normalized, **G** = annealed, **K** = cold drawn, **V + K** = heat treated and cold drawn machining steels can be milled very well in case of high sulphur content. |
| 9 SMn 28 | 380...570 | ≦ 0.14 | 23 | 235 | | |
| 9 SMn 36 | 390...580 | ≦ 0.15 | 23 | 235 | | |
| 35 S 20 | 490...660 | 0.35 | 18 | 285 | annealed & temp. steels | |
| 45 S 20 | 590...760 | 0.45 | 14 | 325 | | |
| 60 S 20 | 660...870 | 0.60 | 9 | 355 | | |

## Stainless steels

DIN 17 440 (Dec. 72)

| Symbol | Similar to Eurostandard 88–71 | Density g/m³ | State | Tensile strength N/mm² | Yield point N/mm² | Breaking strain % |
|---|---|---|---|---|---|---|
| **Ferrous steels** | | | | | | |
| X 7 Cr 13 | X 6 Cr 13 | 7.7 | annealed<br>tempered | 450…650<br>550…700 | 250<br>400 | 20<br>18 |
| X 7 CrAl 13 | X 6 CrAl 13 | 7.7 | annealed<br>tempered | 450…650<br>550…700 | 250<br>400 | 20<br>18 |
| X 8 Cr 17 | X 8 Cr 17 | 7.7 | annealed | 450…600 | 270 | 20 |
| X 6 CrMo 17 | X 8 CrMo 17 | 7.7 | annealed | 450…650 | 270 | 20 |
| **Martensitic steels** | | | | | | |
| X 10 Cr 13 | X 12 Cr 13 | 7.7 | annealed<br>tempered | 550…700<br>600…750 | 300<br>450 | 20<br>18 |
| X 20 Cr 13 | X 20 Cr 13 | 7.7 | tempered | 800…950 | 550 | 15 |
| X 12 CrMoS 17 | X 14 CrMoS 17 | 7.7 | annealed<br>tempered | 550…700<br>700…850 | 300<br>450 | 20<br>12 |
| X 22 CrNi 17 | X 21 CrNi 17 | 7.7 | tempered | 800…950 | 600 | 14 |
| **Austenitic steels** | | | | | | |
| X 5 CrNi 18 9 | X 6 CrNi 18 10 | 7.9 | quenched | 500…700 | 185 | 50 |
| X 10 CrNiTi 18 9 | X 6 CrNiTi 18 10 | 7.9 | | 500…750 | 205 | 40 |
| X 5 CrNiMo 18 10 | X 6 CrNiMo 17 12 2 | 7.95 | | 500…700 | 205 | 45 |
| X 10 CrNiMoTi 18 10 | X 6 CrNiMoTi 17 12 2 | 7.95 | | 500…750 | 265 | 40 |
| X 5 CrNiMo 18 10 | X 6 CrNiMo 17 13 37 | 7.95 | | 500…700 | 205 | 45 |
| X 2 CrNiMo 18 16 | X 3 CrNiMo 18 16 4 | 8.0 | | 500…700 | 195 | 45 |
| X 2 CrNiN 18 10 | — | 7.9 | | 550…750 | 270 | 40 |
| X 2 CrNiMoN 18 13 | — | 7.95 | | 600…800 | 300 | 40 |

| Symbol | State | Yield point at … °C (N/mm²) 50 | 100 | 150 | 200 | 250 | 300 | 400 | 500 | Hardn. (20°C) HB |
|---|---|---|---|---|---|---|---|---|---|---|
| X 7 Cr 13 | annealed | 240 | 235 | 230 | 225 | 225 | 220 | 195 | — | 130…180 |
| X 10 Cr 13 | annealed | 285 | 275 | 265 | 260 | 255 | 245 | 215 | — | 140…180 |
| | tempered | 430 | 420 | 410 | 400 | 382 | 365 | 305 | — | 170…210 |
| X 20 Cr 13 | tempered | 430 | 420 | 410 | 400 | 382 | 365 | 305 | — | 230…275 |
| X 22 CrNi 17 | tempered | 565 | 540 | 520 | 505 | 490 | 470 | 375 | — | 225…275 |
| X 5 CrNi 18 9 | quenched | 175 | 155 | 140 | 127 | 118 | 110 | 98 | 92 | 130…180 |
| X 10 CrNiTi 18 9 | | 190 | 176 | 165 | 155 | 145 | 136 | 125 | 119 | 130…190 |
| X 10 CrNiMoTi 18 10 | | 205 | 190 | 176 | 165 | 155 | 145 | 135 | 129 | 130…190 |
| X 2 CrNiN 18 10 | | 245 | 245 | 175 | 157 | 145 | 136 | 125 | 119 | 140…200 |
| X 2 CrNiMoN 18 13 | | 265 | 225 | 197 | 178 | 165 | 155 | 145 | 138 | 150…210 |

| Symbol | Elasticity modulus at … °C 10³ N/mm² 20 | 100 | 200 | 300 | 400 | 500 | Thermal expansion at temperatures between 20° C and … °C α in 10⁻⁶ m/m °C 100 | 200 | 300 | 400 |
|---|---|---|---|---|---|---|---|---|---|---|
| X 7 Cr 13<br>X 7 CrAl 13 | 216 | 213 | 207 | 200 | 192 | — | 10.5 | 11.0 | 11.5 | 12.0 |
| X 6 CrMo 17 | 126 | 213 | 207 | 200 | 192 | — | 10.0 | 10.5 | 10.5 | 10.5 |
| X 10 Cr 13<br>X 20 Cr 13 | | | | | | | 10.5 | 11.0 | 11.5 | 12.0 |
| X 12 CrMoS 17 | | | | | | | 10.0 | 10.5 | 10.5 | 10.5 |
| X 22 CrNi 17 | | | | | | | 10.0 | 10.5 | 11.0 | 11.0 |
| X 8 Cr 17 | 220 | 218 | 212 | 205 | 197 | — | 10.0 | 10.0 | 10.5 | 10.5 |
| X 5 CrNi 18 9<br>X 10 CrNiTi 18 9 | 200 | 194 | 186 | 179 | 172 | 165 | 16.0 | 17.0 | 17.0 | 18.0 |
| X 5 CrNiMo 18 10 | | | | | | | 16.5 | 17.5 | 17.5 | 18.5 |
| X 10 CrNiMoTi 18 10 | | | | | | | 16.5 | 17.5 | 18.5 | 18.5 |
| X 5 CrNiMo 18 12 | | | | | | | 16.5 | 17.5 | 17.5 | 18.5 |
| X 2 CrNiMo 18 16 | | | | | | | 16.5 | 17.5 | 18.0 | 18.5 |

# Designation of steels

Tentative standard DIN 1599 (Feb. 64)

The symbols for mild-and-bar steel are primarily designated by the standard codes for steel on tags and stickers.
The shape of the tags indicates the steel group.
The colour of the tags indicates the tensile strength or the carbon content.

| Minimum tensile strength N/mm² ≈ | C-content in % | Colours of the tags or the stickers | Steel grouping: standard structural steels as per DIN 17100 | Steel grouping: machinery steel as per DIN 1651 | Steel grouping: Plain case-hardened per DIN 17210 — Plain annealed and steel as good quality | Steel grouping: Plain case-hardened per DIN 17210 — Plain annealed and steel as per DIN 17200 refined steel |
|---|---|---|---|---|---|---|
| | | | Shapes of the hanging tags or stickers: 105 x 74 | 100 | 74 x 74 | 100 |
| 320 | < 0.10 | white | St 33 1) | 9 S 20, 9SMn28, 9SPb28, 9 SMn Pb 28 | – | – |
| 330 | ≈ 0.10 | yellow | St 34 1) | 10 S 20 | C 10 | Ck 10 |
| 360 | ≈ 0.15 | red | St 37 1) | | C 15 | Ck 15 |
| 410 | ≈ 0.22 | green | St 42 1) | | C 22 | Ck 22 |
| 490 | ≈ 0.35 | blue | St 50 2) | 35 S 20 | C 35 | Ck 35 |
| 590 | ≈ 0.45 | lilac | St 60 2) | 45 S 20 | C 45 | Ck 45 |
| 690 | ≈ 0.60 | brown | St 70-2 3) | 60 S 20 | C 60 | Ck 60 |
| 510 | | alumi-nium | St 52-3 4) | – | – | – |

1) Quality groups 1, 2, & 3
2) Quality groups 1 & 2
3) Quality group 2
4) Quality group 3

## Designation of cutting tool bits

**DIN 4982**

On the left side of the shank if seen from the end of the shank:
- Manufacturer's mark
- DIN number for cutting tool bit
- Group of application

On the back side:
- Characteristic colour
- Group of application
- Hard metal quality of manufacturer

**Machining–Groups of application** DIN 4990 (July 72)

| Code | Colour | Material | Manufacturing methods and conditions |
|---|---|---|---|
| P 01 | blue | Steel<br>Cast steel | Precision turning and drilling<br>High cutting speed, low feeds |
| P 10 | | Steel<br>Cast steel | Turning, copying, thread cutting also milling<br>Cutting speed high, low to moderate feeds |
| P 20 | | Steel, Cast steel<br>Longitudinally stressed tempered iron | Turning, copying, milling<br>Moderate cutting speeds and feeds<br>Planing with low feeds |
| P 30 | | Steel, Cast steel<br>Longitudinally stressed tempered iron | Turning, planing, milling. Moderate to low cutting speed, moderate to high feeds even it operational conditions are unfavourable [1] |
| P 40 | | Steel<br>Cast steel with cavaties and sand inclusions | Turning, planing, slotting. Partial operation of automatic lathes, low cutting speed, large feed, large rake angle possible even if operational conditions are unfavourable [1] |
| P 50 | | Steel, Cast steel of medium and low strength, also with cavaties and sand inclusions | Turning, planing, slotting operation of automatic lathes, low cutting speed, large feed with the highest demand on tensile stress of hard metal [1] |
| M 10 | yellow | Magnesium steel, cast steel cast iron, alloyed cast iron | Turning, medium to high cutting speed, low to moderate feed |
| M 20 | | Steel austenitic, magnesium steel, cast steel, spherolite cast iron, malleable cast iron | Turning, milling, medium cutting speed, medium feed |
| M 30 | | Steel, austenitic steels, heat treatable alloys, cast steel, cast iron | Turning, planing, milling, medium cutting speed, medium to high feed |
| M 40 | | Steels of low strength soft steel in automatic machines mild steel, nonferr. metal | Turning, profile turning, trimming, specially in automatic machines |
| K 01 | red | Hardened steel over 60 HRC, cast iron with high hardness AL-alloy with high Si content, synthetic materiols with effective wear & tear. Hard paper, ceramic working materials | Turning, precision turning, fine boring, finishing, scraping & trimming |
| K 10 | | Hardened steel, cast iron over 220HB, malleable cast iron giving short chips in cutting Cu-alloy, silicon Al-alloys, synthetic steel, hard rubber, hard paper, glass porcelain stones | Turning, boring, counter sinking reaming, milling, broaching, scraping and trimming |
| K 20 | | Cast iron under 220 HB, Cu, brass, Al other non-ferrous metals. Laminated wood with considerable wear and tear. | Turning, planing, counter-sinking reaming, milling, broaching in case of high demands on the toughness of the hard metal. |
| K 30 | | Steel with low strength<br>Cast iron with low hardness<br>Laminated wood | Turning, planing, shaping, milling wide rake angle possible even under unfavourable operative conditions [1] |
| K 40 | | Non-ferrous metals, soft and hard woods in naturale state | Turning, planing, slotting wide rake angle possible even under unfavourable operative conditions. [1] |

Feeds and toughness of the cutting material in increasing order

Increasing cutting speeds, resistance against wear and tear of the cutting tool metal

Increasing order of feed and toughness of the cutting metal

Resistance against wear & tear of the cutting tool metal

Increasing order of feed and toughness of the cutting food metal

Increasing order of cutting speeds, resistance against wear and tear of the cutting tool metal

Chipping-main graphs P.M.K.

[1] Unfavourable operating conditions exist for instance with homogenous materials, cast and forged crusts, variable hardness, variable cutting depths, intermittant cuts, vibration during processing and in non-circular workpieces.

| Designation | Symbol | Minimum content | Properties | Use |
|---|---|---|---|---|
| **Copper** | | | | DIN 1787 (Jan. 73) |
| O-bearing copper | E-Cu 57 | ≧ 99.9% Cu | Soft, tough, good conductor of electricity weldable, can be hard sold. Hydrogen resistent | Semi-finished products, e.g. pipes, bars, sheets, wires for apparatus piping tubes. electrical techniques. |
| O-free copper | OF-Cu | ≧ 99.95% Cu | | |
| O-free copper with deoxidized phosphorus | SE-Cu | ≧ 99.9% Cu | | |
| | SF-Cu | ≧ 99.9% Cu | | |
| **Lead** | | | | DIN 1719 (April 63) |
| High quality lead 99.99 | Pb 99.99 | 99.99% Pb | Soft, can be casted, soldered or welded. | Red lead, Akku-sheets |
| Metallurgical lead 99,94 | Pb 99.94 | 99.94% Pb | | Alloys, Alloys except |
| Metallurgical lead 99.90 | Pb 99.90 | 99.90% Pb | | for chemical apparatus |
| **Zinc** | | | | DIN 1706 (March 74) |
| High grade zinc | Zn 99.995 Zn 99.95 | 99.995% Zn 99.95% Zn | Can be casted, weather resistant | Galvanization, zinc sheets, strip wires and for alloying purposes |
| Metallurgical zinc | Zn 99.5 Zn 97.5 | 99.5% Zn 97.5% Zn | | |
| **Tin** | | | | DIN 1704 (June 73) |
| Tin 99.90 Tin 99.75 | Sn 99.90 Sn 99.75 | 99.90% Sn 99.75% Sn | Soft, castable, can be rolled into foil | Coating, alloying metal, tin plates, strips, foils |
| **Nickel** | | | | DIN 1701 (July 58) |
| Nickel 99.6 Nickel 98 | Ni 99.6 Ni 98 | 99.6% Ni 98% Ni | Tensile strength 390-740 N/mm² | Chemical appliances, electrodes, teeth fillings |
| **Aluminium** | | | | DIN 1712 (Oct. 61) |
| Metallurgical aluminium | Al 99.8 H Al 99.5 H Al 99 H | 99.8% Al 99.5% Al 99% Al | Can be casted and welded Strength 150 N/mm² | Supplied as pig Al., blocks, rolled and pressed bars, forged bars, plates |
| Pure aluminium | Al 99.8 | 99.8% Al | Supplied as sheet, bands, strips, pipes, foils, plates, rods, profile, wires, rivets, compressed parts | Meets high requirements in the chemical industry |
| | Al 99.7 | 99.7% Al | | |
| | Al 99.5 | 99.5% Al | | Chem. industry, El. engineering, shipbuild. |
| | Al 99 | 99% Al | | For general use |
| | Al 98 | 98% Al | | Not for chemically stressed parts. e.g. kitchenware, roofing |
| High grade aluminium | Al 99.99 R | 99.99% Al | Supplied as pig. Al., blocks, rolled, pressed and forged bars, rolled plates, shots gravel | For subsequent manufacture for the kneading and foundary purposes |
| High grade Al-alloys | Al R Mg 0.5 | 99.38% Al +0.5% Mg | | |
| High grade Al-alloys | Al R Mg 1 | 98.98% Al +1% Mg | | |
| High grade Al-alloys | Al R Mg 2 | 97.98% Al + 2% Mg | | |

Metallurgical aluminium is obtained from the metallurgical operations of molten aluminium.

Pure aluminium for semi-finished products is not only produced from aluminium but can also be obtained by remelting scrap aluminium. The permissible admixtures, therefore deviate from those of metallurgical aluminium.

Pure aluminium is manufactured directly from metallurgical aluminium or scrap aluminium.

## Symbols for non-ferrous metals

DIN 1700 (July 54)

Symbols consist of distinguishing mark for

Example: **G-Al Si 12 g**

| **manufacture & usage** | hyphen | **composition** | gap | **special properties** |
|---|---|---|---|---|

**G** = Casting
**GD** = Pressure casting
**GK** = Chill casting
**GZ** = Centrifugal casting
**V** = Blending alloys
**GI** = Antifriction or bearing metals
**L** = Solders

1. Chemical symbol of the basic constituents together with the index number of its contents
2. Chemical symbol signifying the alloy constituents along with the index number of its contents (depending on the quantity of the contents)

The characteristic numbers can be dropped if the symbols used identify the alloy sufficiently.

If required
1. Characteristic letters for the methods of treatment in accordance to DIN 1750
2. Minimum value of tensile strength prefixed by the alphabet F

Example: AlMg3F17 = Aluminium forging alloy with 3% Mg 170 N/mm² tensile strength.

The data for characterizing the materials should be limited to the required sizes

Examples:

Symbols without using ciphering

**GI-Pb** = Lead-alkali-bearing metal with ≈ 0,6% Ca, 0,8% Ba, 0,5% Na, 0,04% Li, 0,05% Mg

Symbols without using ciphering for basic material

**AlMg3Si** = Aluminium forging alloys with ≈ 3% Mg, 0,6% Si, 0,5% Mn
**G-AlSi12** = Aluminium casting alloy with ≈ 12% Si, 0,4% Mn
**GD-ZnAl4Cu1** = High grade zinc die-casting alloy with ≈ 4% Al, 1% Cu, 0,05% Mg

Symbols with ciphering for basic material

**Ni88Cr** = Nickel alloy with ≈ 88% Ni, 10% Cr, 1% Mn
**GI-Sn80** = White metal (Zinc-bearing metal) with ≈ 80% Sn, 6% Cu, 12% Sb, 2% Pb
**L-Sn60** = Tin solders with ≈ 60% Sn, 3% Sb, rest Pb

## Symbols indicating the state of hardness and surface finish

The state of hardness is indicated by the specifications of the tensile strength prefixed with the alphabet F (strength). For commercial production where no particular tensile strength is used, a letter is used in the place of tensile strength.

| | Degree of hardness | Example |
|---|---|---|
| **F40** | = tensile strength 390 N/mm² | AlCuMg1F40 |
| **w** | = soft | AlCuMg1w |
| **h** | = hard | AlCuMg2h |
| **wh** | = hard-rolled | A199wh |
| **zh** | = hard drawn | AlMg1zh |
| **p** | = pressed hard | AlMg2p |
| **150HV** | = Vickers hardness 150 | |

| | Physical properties Surface finish | Examples |
|---|---|---|
| **bk** | = polished | MgMn2bk |
| **gb** | = etched | AlMg2gb |
| **g** | = annealed | G-AlSi12g |
| **wa** | = hot hardening | G-AlSi5Mgwa |
| **ka** | = cold hardening | G-AlSi5Mgka |
| **dek** | = can be oxidized giving a decorative appearance | AlMgSi1dekF28 |

## Manganese alloys Forging alloys

DIN 1729 (May 63)

| Symbol | Colour code | Alloying parts | Supplied as | Properties | Use |
|---|---|---|---|---|---|
| **MgMn2** | Yellow-black-red | 2% Mn Rest Mg | Sheets Pipes | Resistant to corrosion easily weldable | Profile sheets, coating, tanks, armatures |
| **MgAl3Zn** | Yellow-black-green | 3% Al 1% Zn | Rods Profiles | Medium strength weldable | Medium mechanical loads, yet good chemical stability |
| **MgAl6Zn** | Yellow-black-white | 6% Al 1% Zn | Forged steel Welding wires | Medium to high tensile strength, limited weldability | Construction parts subjected to medium to high mechanical loads |
| **MgAl8Zn** | Yellow-black-blue | 8% Al 1,2% Zn | Rods Profiles | Highest tensile strength not weldable | Construction parts to high mechanical loads |

easily to form, cut or to be machined

# Copper and copper alloys (Sheets and strips)

DIN 17670 (June 74)

| Designation | Symbol | Tensile strength N/mm² | 0.2 Limit N/mm² | Breaking strain % | Brinell Hardness HB 2.5/62.5 | Previous Symbol |
|---|---|---|---|---|---|---|
| **Copper** material in accordance to DIN 1787 (Jan. 73) | SW-Cu F20 | 200...250 | 100 | 42 | 55 | --- |
| | SW-Cu F30 | 290...360 | 250 | 6 | 95 | --- |
| | SF-Cu F22 | 220...250 | 140 | 45 | 55 | --- |
| | SF-Cu F37 | ≈360 | 320 | 3 | 105 | --- |
| **Brass** materials in accordance to DIN 17660 (Apr. 74) | CuZn5 F27 | 260...320 | 200 | 19 | 85 | Ms 95 |
| | CuZn20 F33 | 320...390 | 200 | 28 | 100 | Ms 80 F33 |
| | CuZn30 F43 | 420...520 | 340 | 15 | 130 | Ms 70 |
| | CuZn33 F54 | ≈530 | 480 | – | 160 | Ms 67 F54 |
| | CuZn36 F62 | ≈510 | 580 | – | 180 | Ms 63 F62 |
| **High strength brass** materials in accordance to DIN 17660 (Apr. 74) | CuZn20Al F35 | ≈340 | 140 | 30 | 85 | SoMs 76 F38 |
| | CuZn31Si F45 | 440...510 | 220 | 25 | 115 | SoMs68 F45 |
| | CuZn39Sn F35 | ≈340 | 140 | 30 | 100 | SoMs 60 F38 |
| **Tin bronzes** materials in accordance to DIN 17662 (Apr. 74) | CuSn2 F26 | ≈260 | 150 | 50 | 60 | SnBz2 F26 |
| | CuSn6 F35 | 340...400 | 250 | 55 | 85 | SnBz6 F36 |
| | CuSn8 F53 | 520...590 | 420 | 23 | 165 | SnBz8 F53 |
| | CuSn6 Zn F70 | 690...760 | 620 | 7 | 215 | MSnBz6 F70 |
| **German silver** materials in accordance to DIN 17663 (Apr. 74) | CuNi12Zn24 F35 | 340...410 | 290 | 45 | 85 | Ns6512 F35 |
| | CuNi12Zn30PbF50 | 490...590 | 410 | 12 | 155 | Ns5712PbF50 |
| | CuNi18Zn20 F38 | 370...430 | 290 | 40 | 90 | Ns6218 F38 |
| | CuNi18Zn20 F62 | ≈610 | 540 | – | 185 | Ns6218 |
| | CuNi25ZnZn15F47 | 460...540 | 290 | 22 | 130 | Ns6025 F47 |
| **Copper-nickel alloys** DIN 17664 (Apr. 74) | CuNi5Fe F24 | 240 | 80 | 40 | 65 | CuNi5Fe F24 |
| | CuNi20Fe F30 | 290 | 100 | 35 | 85 | CuNi20Fe F34 |
| | CuNi44 F45 | 440 | – | 42 | 95 | CuNi44 F50 |
| **Aluminium bronze** DIN 17665 (Apr. 74) | CuAl5 F45 | 440 | 240 | 20 | 130 | AlBz5 F45 |
| | CuAl8Fe F45 | 440 | 220 | 25 | 110 | AlBzFe F45 |
| | CuAl10Ni F56 | 550 | 240 | 8 | 160 | AlBz10Ni |

# Copper casting materials

| | | | | | 10/1000 | ϱ kg/dm³ | Supplied as |
|---|---|---|---|---|---|---|---|
| **Copper** DIN 17655 (July 71) | G-Cu | 200 | 50 | 25 | | 8,9 | Shaped casting |
| | G-CuL45 | 150 | 40 | 25 | | 8,9 | Shaped casting |
| | G-CuCr F35 | 350 | 250 | 10 | | 8,9 | Shaped casting |
| **Tin bronze Red alloy** DIN 1705 (June 73) | G-CuSn 12 | 260 | 260 | 12 | 80 | 8,6 | Sand casting |
| | GZ-CuSn12Ni | 300 | 180 | 8 | 100 | 8,6 | Centrifugal casting |
| | G-CuSn12Pb | 260 | 140 | 10 | 80 | 8,7 | Sand casting |
| | GZ-CuSn10Zn | 270 | 150 | 7 | 85 | 8,7 | Centrifugal casting |
| | GZ-CuSn7ZnPb | 270 | 130 | 13 | 75 | 8,8 | Centrifugal casting |
| | G-CuSn2ZnPb | 210 | 90 | 18 | 60 | 8,7 | Sand casting |
| **Cast brass** DIN 1709 (June 73) | G-CuZn33Pb | 180 | 70 | 12 | 45 | 8,5 | Sand casting |
| | GK-CuZn38Al | 380 | 130 | 20 | 75 | 8,5 | Chilled casting |
| | GZ-CuZn34Al12 | 620 | 260 | 14 | 150 | 8,6 | Centrifugal casting |
| | GD-CuZn15Si4 | 550 | 300 | 8 | 125 | 8,6 | Pressure die casting |
| **Aluminium bronze** DIN 1714 (June 73) | G-CuAl10Fe | 500 | 180 | 15 | 115 | 7,5 | Sand casting |
| | GK-CuA10Ni | 600 | 300 | 12 | 150 | 7,6 | Chilled casting |
| | GZ-CuAl11Ni | 750 | 400 | 5 | 185 | 7,6 | Centrifugal casting |
| **Tin-lead-bronze** DIN 1716 (June 73) | G-CuPb5Sn | 240 | 130 | 15 | 70 | 8,7 | Sand casting |
| | GZ-CuPb15Sn | 220 | 110 | 7 | 65 | 9,1 | Centrifugal casting |
| | G-CuPb20Sn | 160 | 90 | 6 | 50 | 9,3 | Sand casting |

# Aluminium alloys

| Binary alloys | Ternary alloys | | | | Quarternary alloys |
|---|---|---|---|---|---|
| | | | | | |
| AlMn<br>AlMg | AlMgMn | AlMgSi | AlCuMg | AlCuSi | AlCuMgPb<br>AlMgSiPb<br>AlZnMgCu |

## Aluminium-wrought alloys for semi-finished products

DIN 1725 Pg. 1 (Feb. 67)

| Symbol | Colour code | Alloy constituents ≈ %(Rest Al) | Moulding properties | Weldability | Machinability | Use |
|---|---|---|---|---|---|---|
| AlMn | Purple | Mn1Mg0,2 | Very good | Very good | Limited | Architecture, roofing, |
| AlMg1 | Green-blue | Mg1Cr0,1Mn0,1 | Very good | Very good | Limited | food industry |
| AlMg2 | Green-purple | Mg2Mn0,2Cr0,1 | Very good | Good | Limited | Architect., Automobile industry |
| AlMg5 | Green-black | Mg5Mn0,3Cr0,2 | Good | Good | Good | Rotating parts, ship building |
| AlMgMn | Green | Mg2Mn1Cr0,1 | Good | Very good | Limited | Apparatus, ship building |
| E-AlMgSi | White-white | Mg0,6Si0,5 | | | Good | Ropes wires f. el. engineering |
| AlMgSi1 | White | Si1Mg1Mn0,5 | Good | Good | Sufficient | Architecture, automobile and food industry, ship building |
| AlMgSiPb | White-black | Si1Mg1Mn0,5 | – | – | Good | Rotating parts (aut. machines) |
| AlCuMg0,5 | Red-yellow | Cu2Mg0,5Pb1 | Good | – | – | Rivets |
| AlCuMg1 | Red | Cu4Mg0,5Mn0,8 | Sufficient | Good resistance welding | Good | Automobile and aircraft |
| AlCuMg2 | Red-green | Cu4,5Mg1,5Mn0,5 | Sufficient | | Good | industry, mechanical engineer. |
| AlCuMgPb | Red-black | Cu4Mg1Pb1 | – | – | Very good | Rotating parts (autom. machines) |
| AlZnMgCu1.5 | Blue-red | Cu1.5Mg2.5Zn6 | Limited | Good resistance welding | Good | Mining, automobile and aircraft industry, machine building industry |

## Aluminium casting alloys

DIN 1725 Pg 2 (Sept. 70)

| Symbol | Alloy (Rest Al) % | | | Tensile strength N/mm² | Strain $\sigma_5$ % | Bending strength N/mm² | 0.2 Limit N/mm² | Machinability | Weldability |
|---|---|---|---|---|---|---|---|---|---|
| G-AlSi 12 | Si 12 | Mn | 0.4 | 160 | 5…10 | 60 | 70 | Good | Very Good |
| G-AlSi 10 Mg | Si 10 | Mg | 0.3 | 170 | 2… 6 | 70 | 80 | Good | Very Good |
| G-AlSi 8 Cu3 | Si 8 | Cu | 3 | 160 | 1… 3 | 60 | 100 | Very Good | Very Good |
| G-AlSi 5 Mg | Si 5 | Mg | 0.4 | 140 | 1… 3 | 60 | 100 | Very Good | Good |
| G-AlMg5 | Mg 5 | Mn | 0.4 | 100 | 3… 8 | 60 | 100 | Very Good | Good |
| GD-AlMg9 | Mg 9 | Si | 2.5 | 200 | $\sigma_{10}$:5 | 60 | 140 | Very Good | No |
| G-AlCu4Ti wa | Cu 4 | Ti | 0.3 | 290 | 3… 8 | 80 | 200 | Very Good | Limited |
| G-AlCu4Ti Mg | Cu 4 | Ti | 0.3 | 340 | 3…10 | 80 | 240 | Very Good | Limited |

G = Casting, GK = Chilled casting, GD = Pressure casting, ka = cold tempered, wa = hot tempered

## Designations and tensile strength for Aluminium–forging alloys

| Symbol (for materials and strength properties) | Physical state | Tensile Strength N/mm² | 0.2-Limit N/mm² | Breaking strain % | Hardness HB 10 | Supplied as Sheets DIN 1745 (Dec. 68) | Pipes DIN 1746 (Dec. 68) | Rods DIN 1747 (Dec. 68) | Profiles DIN 1748 (Dec. 68) | Forged pieces DIN 1749 (Dec. 68) |
|---|---|---|---|---|---|---|---|---|---|---|
| AlMnF13 | Semi-hard | 130 | 90 | 6 | 390 | 6 mm | -10 mm | ■ | – | |
| AlMg 1 wh | Rolled | without specifications | | | | every thickn. | Wall thickn. | – | | |
| AlMg1F10 | Soft | 100 | 40 | 20 | 290 | upto 6 mm | upto 10mm | ■ | ■ | |
| AlMg1F13 | Semi-hard | 130 | 90 | 7 | 390 | upto 6 mm | upto 10mm | ■ | | |
| AlMg1F16 | Hard | 160 | 140 | 4 | 490 | upto 6 mm | upto 3 mm | ■ | | |
| AlMg2F15 | Soft | 150 | 60 | 19 | 390 | upto 6 mm | upto 10mm | ■ | ■ | |
| AlMgSi1F28 | Hot-tempered | 270 | 180 | 12 | 780 | upto 20 mm | per | ■ | ■ | ■ |
| AlCuMg1F40 | Cold tempered | 390 | 260 | 15 | 980 | upto 10 mm | 1…6 | ■ | ■ | ■ |
| AiCuMg2plw | Plated soft | 240 | – | 14 | – | upto 6 mm | – | – | | |
| AlZnMgCu1.5 F52 | Hot tempered | 510 | 430 | 7 | 1370 | upto 25 mm | 1…20 | ■ | ■ | ■ |

## Lead and tin alloys for sleeve bearings

DIN 1703 (April 74)

| Symbol | Composition | Rest | Melting range (Moulding range) °C | Hardness HB 250/180 at 50 °C | 100 °C | Density g/cm³ | Use |
|---|---|---|---|---|---|---|---|
| **Lg Pb Sb 14** | Sb 14 As 1 Sn 1 | Pb | 245…420 (450…500) | 17.5 | 12.5 | 10.5 | Thin bearing layer with temperatures around 100 deg. C |
| **Lg Pb Sn 9 Cd** | Sn 9 Sb 14 Cu 1 Cd 0.5 | Pb | 240…400 (480…520) | 21 | 14 | 10.0 | Highly suitable for bearing and loads |
| **Lg Sn 80** | Sb 12 Cu 6 Pb 2 | Sn | 183…400 (480…520) | 20 | 10 | 7.4 | Low impact resistant, heavy loading |
| **Lg Pb Sn 10** | Sn 10 Sb 15.5 Cu 1 | Pb | 325…380 (480…520) | 16 | 9 | 10.0 | Normal requirements |
| **Lg Sn 89** | Sb 7.5 Cu 3.5 | Sn | 233…360 (440…460) | 17 | 10 | 7.3 | For high impact resistance |

## High grade zinc alloys

DIN 1743 (June 67)

| | Symbol | Composition | Tens. strength N/mm² | Hardn. HB 10 | Use |
|---|---|---|---|---|---|
| Cast parts made of pressure sands and chilled castings | **GD-Zn Al4** | Al4 Cu 0.1 Mg 0.04 Zn | 250…290 | 80 | Parts with high measurement accuracy |
| | **G-ZnAl4 Cu3** | Al4 Cu3 Mg 0.04 Zn | 220…250 | 95 | Sand and chilled cast parts, stretching forms |
| | **GK-Zn Al4 Cu3** | Al4 Cu3 Mg 0.04 Zn | 240…270 | 105 | |
| | **GK-ZnAl6Cu1** | Al5.5 Cu 1.4 Zn | 220…250 | 85 | For difficult cast parts |

## Soft solders for heavy metals

DIN 1707 (Sept. 73)

| Group[1] | Symbol | Compos. % | Rest | Fusion range | Density g/cm³ | Sold. Technique K | F | T | I[2] | Use |
|---|---|---|---|---|---|---|---|---|---|---|
| A Ah | **L-Pb Sn 40 Sb** | Sn 40 Sb 1.5 | Pb | 186…235 | 9.4 | 0 | 0 | 0 | | Solder for sheet metal |
| A Aa | **L-Pb Sn 8 (Sb)** | Sn 8 Sb 0.3 | Pb | 280…305 | 10.6 | | 0 | 0 | 0 | Cooler; thermostats |
| A Ah | **L-Sn 50 Pb Sb** | Sn 50 Sb 2 | Pb | 186…205 | 8.7 | 0 | 0 | 0 | | High grade plumbing work |
| A Aa | **L-Pb Sn 40(Sb)** | Sn 40 Sb 0.3 | Pb | 183…235 | 9.3 | 0 | 0 | 0 | | Tinning, fine sheet metal packing |
| A Af | **L-Pb Sn 2** | Nn 2 | Pb | 320…325 | 11.1 | 0 | 0 | | | Fine sheet metal packing |
| A Af | **L-Sn 60 Pb Cu** | Sn 50 | Pb | 183…215 | 8.9 | 0 | 0 | 0 | | Copper pipes installations |
| B | **L-Sn 60 Pb Cu** | Sn 60 Cu 0.2 | Pb | 183…190 | 8.5 | | | 0 | | Printed circuit |
| B | **L-Sn 60 Pb Ag** | Sn 60 Ag 3.5 | Pb | 178…180 | 8.5 | 0 | | 0 | 0 | Electrical equipment fabrication |
| C | **L-Sn Ag 5** | Ag 5 | Sn | 221…240 | 7.2 | 0 | 0 | 0 | 0 | Refrigeration; refined steel |
| C | **L-Pb Ag 5** | Ag 5 | Pb | 304…365 | 11.2 | 0 | 0 | | | For high working temperatures |
| C | **L-Cd Ag 5** | Ag 5 | Cd | 340…395 | 8.3 | | 0 | | | |

[1] Group A: tin-lead-soft solder, tinlead-soft solder
Ah: contains antimony Aa: low content of antimony, Af: without antimony
B: tin-lead soft solder with silver or copper additive
C: special soft solder

[2] Soldering process: K: piston soldering; F: flame soldering; T: dip soldering; I: Induction soldering

## Copper solders (hard solders for heavy metals)

DIN 8513 (Feb. 73)

| Symbol new | existing | Composition % | Rest | Working temp. °C | Fusion range °C | Used for |
|---|---|---|---|---|---|---|
| **L-Cu** | L-Cu | Cu 99.99 | – | 1100 | 1083 | Plain steels |
| **L-Cu P8** | L-Cu P8 | P8 | Cu | 710 | 710 | Copper |
| **L-Cu Sn 12** | L-Sn Bz 12 | Sn 12 P 0.2 | Cu | 990 | 825…990 | Iron and nickel workpieces |
| **L-Cu Zn 40** | L-Ms 60 | Cu 60 | Zn | 900 | 890…900 | Steel, malleable casting, copper alloys |
| **L-Cu Zn 39 Sn** | L-SO Ms | Cu 60 Sn 1.0 | Zn | 900 | 870…890 | Cast iron |
| **L-Zn Cu 42** | L-Ms 42 | Cu 42 | Zn | 845 | 835…845 | German silver |
| **L-Cu Ni10 Zn42** | L-Ns | Cu 48 Ni 10 | Zn | 910 | 890…920 | Nickel, cast iron |

## Welding admixed material for copper

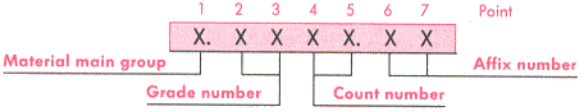
DIN 1733 (Aug. 63)

| | | | | | |
|---|---|---|---|---|---|
| | **S-Cu** | Cu 99 Zn 0.5 | Sn 0.5 | 1070…1080 | Types of copper in accordance to DIN 1787 |
| Welding rods | **S-Cu Si** | Cu 94 Si 4 | Mn 1 | 910…1025 | Silicon bronze |
| Welding wires | **S-Ms 60** | Cu 60 Si 0.5 Sn 0.5 | Zn Rest | 890…900 | Brass, special brass |
| | **S-Al Bz 8** | Cu 90-Al 8.5 | Mn 1.5 | 1030…1040 | Aluminium bronze, corrosion-resistant coating |

# Material numbers

DIN 17007 Pg.1 (Apr. 59)

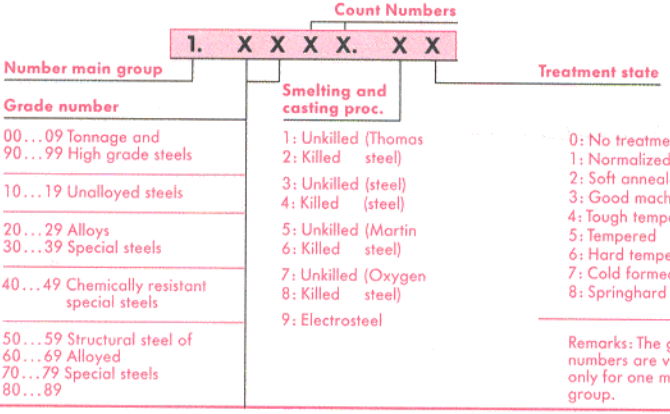
## Construction:




Materials main groups

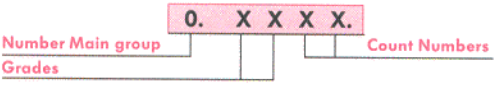
0: Raw iron, ferrous alloy, cast iron (DIN 17007 Pg. 3 Jan. 71)
1: Steel (DIN 17007 Pg. 2 Sep. 61)
2: Heavy metals (except iron) (DIN 17007 Pg. 4 Jul. 63)
3: Light metals (DIN 17007 Pg. 4 Jul. 63)
4...8: Non-metallic products

## Systematics of the main group 1




Remarks: The grade numbers are valid only for one main group.

## Systematics of the main group 0




60...69: Cast irons with lamellar graphite
70...79: Cast irons with nodular graphite
80...89: Malleable castings
90...99: Special cast irons

Remarks: The grading for raw iron has not yet been classified. The gradings 30...49 are pre-alloys.

| Symbol | Material number | Symbol | Material number |
|---|---|---|---|
| cast iron | | cast steel | |
| GG-10 | 0.6010 | GS-38 | 1.0416 |
| GG-20 | 0.6020 | GS-45 | 1.0443 |
| GG-25 | 0.6025 | GS-60 | 1.0553 |
| GG-35 | 0.6035 | GS-70 | 1.0554 |
| GG-40 | 0.6040 | | |
| GGG-40 | 0.7040 | GS-C25 | 1.0619 |
| GGG-50 | 0.7050 | GS-22Mo4 | 1.5419 |
| GGG-60 | 0.7060 | GS-17CrMo5 5 | 1.7357 |
| GGG-70 | 0.7070 | G-X22CrMoV 12 1 | 1.4932 |

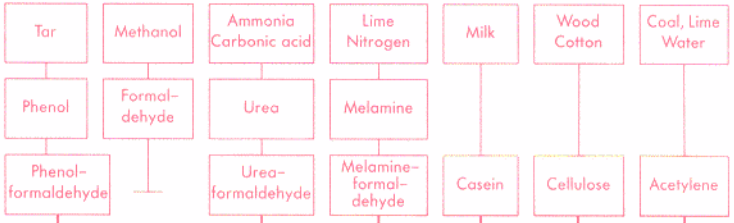
| Symbol | Material number |
|---|---|
| **Universal structural steel** | |
| St 33-1 | 1.0033 |
| St 33-2 | 1.0035 |
| USt 34-1 | 1.0100 |
| RSt 34-2 | 1.0108 |
| St 37-1 | 1.0111 |
| USt 37-2 | 1.0112 |
| St 37-3 | 1.0116 |
| St 42-1 | 1.0130 |
| USt 42-2 | 1.0132 |
| St 42-3 | 1.0136 |
| RSt 46-2 | 1.0477 |
| St 46-3 | 1.0483 |
| St 52-3 | 1.0841 |
| St 50-2 | 1.0532 |
| St 60-1 | 1.0540 |
| St 70-2 | 1.0632 |
| **Non-ageing steels** | |
| ASt 35 | 1.0346 |
| ASt 41 | 1.0426 |
| ASt 45 | 1.0436 |
| ASt 52 | 1.0843 |
| **Stainless steels** | |
| X 7Cr13 | 1.4000 |
| X 7CrAl 13 | 1.4002 |
| X 8Cr17 | 1.4016 |
| X 6 CrMo17 | 1.4113 |
| X 10Cr13 | 1.4006 |
| X 20Cr 13 | 1.4021 |
| X 12CrMoS17 | 1.4104 |
| X 22CrNi17 | 1.4057 |
| X 5CrNi18 9 | 1.4301 |
| X 10 CrNi Ti 18 9 | 1.4541 |
| X 5CrNiMo 18 10 | 1.4401 |
| X 10CrNiMoTi 1810 | 1.4571 |
| X 5CrNiMo 18 12 | 1.4436 |
| X 2CrNiMo 18 16 | 1.4438 |
| X 2CrNiN 18 10 | 1.4311 |
| X 2CrNiMoN 18 | 1.4429 |
| **Free cutting steels** | |
| 9 S 20 | 1.0711 |
| 9 S Mn 28 | 1.0715 |
| 9 S Mn 36 | 1.0736 |
| 35 S 20 | 1.0726 |
| 42 S 20 | 1.0727 |
| 60 S 20 | 1.0728 |

| Symbol | Material number |
|---|---|
| **Case-hardened steels** | |
| Ck 10 | 1.1121 |
| Ck 15 | 1.1141 |
| 15 Cr 3 | 1.7015 |
| 16 MnCr5 | 1.7131 |
| 20 MnCr5 | 1.7147 |
| 15 CrNi6 | 1.5919 |
| 18 CrNi8 | 1.5920 |
| **Tempered steels** | |
| Ck 35 | 1.1181 |
| Ck 45 | 1.1191 |
| Ck 60 | 1.1221 |
| 28 Mn 6 | 1.5065 |
| 38 Cr 2 | 1.7003 |
| 34 Cr 4 | 1.7033 |
| 25 Cr Mo 4 | 1.7218 |
| 32 Cr Mo 12 | 1.7361 |
| **Fine sheets** | |
| St 12 | 1.0330 |
| St 13 | 1.0333 |
| St 14 | 1.0338 |
| TUSt 37 | 1.0110.1 |
| USt 37-2 | 1.0112.5 |
| RSt 42-2 | 1.0132.6 |
| St 50-2 | 1.0532.6 |
| St 52-3 | 1.0841.6 |
| St 60-2 | 1.0542.6 |
| St 70-2 | 1.0632.6 |
| **Spring steels** | |
| 38 Si 7 | 1.0970 |
| 51 Si 7 | 1.0903 |
| 60 Si Cr 7 | 1.0961 |
| 55 Cr 3 | 1.7176 |
| 50 CrV4 | 1.8159 |
| 51 CrMoV4 | 1.7701 |
| **Steels for screws** | |
| USt 36-1 | 1.0201 |
| UQSt 36-2 | 1.0204 |
| USt 38-2 | 1.0217 |
| UQSt 38-2 | 1.0224 |
| RSt 44-2 | 1.0419 |
| 6 P 10 | 1.0744 |
| U 10 S 6 | 1.0706 |

| Symbol | Material number |
|---|---|
| **Copper** | |
| E-Cu 57 | 2.0060 |
| OF-Cu | 2.0040 |
| SE-Cu | 2.0070 |
| SF-Cu | 2.0090 |
| SW-Cu F20 | 2.0076.10 |
| SW-Cu F30 | 2.0076.30 |
| SF-Cu F22 | 2.0090.10 |
| SF-Cu F37 | 2.0090.32 |
| G-Cu | 2.0109.01 |
| G-Cu L50 | 2.0085.01 |
| G-CuCr F35 | 2.1292.61 |
| **Zinc** | |
| Zn 99.995 | 2.2045 |
| Zn 99.95 | 2.2035 |
| Zn 99.5 | 2.2095 |
| Zn 97.5 | 2.2075 |
| **Lead-tin-alloys** | |
| Lg Pb Sb 14 | 2.3313 |
| Lg PbSn9Cd | 2.3309 |
| Lg Sn 80 | 2.3770 |
| Lg PbSn 10 | 2.3310 |
| Lg Sn 89 | 2.3775 |
| **Tin** | |
| Sn 99.95 | 2.3500 |
| Sn 99.90 | 2.3501 |
| Sn 99.75 | 2.3502 |
| Sn 99.00 | 2.3505 |
| **Soft solders** | |
| L-Pb Sn 40Sb | 2.3442 |
| L-PbSn 8(Sb) | 2.3408 |
| L-Sn 50 PbSb | 2.3653 |
| L-PbSn 40(Sb) | 2.3440 |
| L-PbSn 2 | 2.3402 |
| L-Sn 50Pb | 2.3650 |
| L-Sn 60PbCu | 2.3661 |
| L-Sn 60PbAg | 2.3667 |
| L-Sn Ag5 | 2.3690 |
| L-Pb Ag5 | 2.3405 |
| L-CdAg 5 | 2.2480 |
| **Aluminium alloys** | |
| AlMn | 3.0515 |
| AlMg1 | 3.3315 |
| AlMg2 | 3.3325 |
| AlMg5 | 3.3527 |
| E-AlMgSi | 3.2305 |
| AlMgSi1 | 3.2315 |
| AlMgSiPb | 3.0615 |
| AlCuMg0,5 | 3.1305 |
| AlCuMg1 | 3.1325 |
| AlCuMg2 | 3.1355 |
| AlCuMgPb | 3.1645 |
| AlZnMgCu1.5 | 3.4365 |

| Symbol | Material number |
|---|---|
| **Brass** | |
| CuZn5 F27 | 2.0220.26 |
| CuZn20 F33 | 2.0250.26 |
| CuZn30 F43 | 2.0265.30 |
| CuZn33 F54 | 2.0280.32 |
| CuZn36 F62 | 2.0335.34 |
| CuZn20Al F35 | 2.0460.10 |
| CuZn31Si F45 | 2.0490.27 |
| CuZn39Sn F35 | 2.0530.10 |
| **Tin bronze** | |
| CuSn2 F26 | 2.1010.10 |
| CuSn6 F35 | 2.1020.10 |
| CuSn8 F53 | 2.1030.30 |
| CuSn6Zn F70 | 2.1080.32 |
| **German silver** | |
| CuNi12Zn24 F35 | 2.0730.10 |
| CuNi12Zn30Pb F50 | 2.0780.30 |
| CuNi18Zn20 F38 | 2.0740.10 |
| CuNi18Zn20 F62 | 2.0740.32 |
| CuNi25Zn 15 F47 | 2.0750.26 |
| **Copper-Nickel alloys** | |
| CuNi5FeF24 | 2.0862.10 |
| CuNi20FeF30 | 2.0878.10 |
| CuNi44F45 | 2.0842.10 |
| **Aluminium bronzes** | |
| CuAl F45 | 2.0916.30 |
| CuAl8 F45 | 2.0932.97 |
| CuAl10Ni F56 | 2.0966.07 |
| **Hard solders** | |
| L-Cu | 2.0081 |
| L-CuP8 | 2.1465 |
| L-CuSn12 | 2.1055 |
| L-CuZn40 | 2.0367 |
| L-CuZn39Sn | 2.0533 |
| L-ZnCu42 | 2.2310 |
| L-CuNi10Zn42 | 2.0711 |
| **Welding admix for copper** | |
| S-Cu | 2.0181 |
| S-CuSi | 2.1461 |
| S-AlBz8 | 2.0921 |
| **Magnesium alloys** | |
| MgMn2 | 3.5200 |
| MgAl3Zn | 3.5312 |
| MgAl16Zn | 3.5612 |
| MgAl8Zn | 3.5812 |
| **Aluminium cast alloys** | |
| G-AlSi12 | 3.2581.01 |
| G-AlSi10Mg | 3.2381.01 |
| G-AlSi8Cu3 | 3.2161.01 |
| G-AlSi5Mg | 3.2341.01 |
| G-AlMg5 | 3.3561.01 |
| GD-AlMg9 | 3.3292.05 |
| G-AlCu4Ti wa | 3.1841.61 |
| G-AlCu4TiMg | 3.1371.41 |

# Synthetic materials




| Phenoplastics | Synthetic resins | | | Aminoplastics | |
|---|---|---|---|---|---|
| Trade names | | | | Trade names | |
| Bakelite<br>Dekorite<br>Resinol<br>Trolitan<br>Trolon<br>Urbanite | Type 11 to 83 | Moulded plastics | Type 156 to 130 | Pellopas<br>Resopal<br>Ultrapas<br>Duramine<br>Supraplast<br>Melopas | not laminated |
| Araldite<br>Formolite P 1600 | Cast resin | | | | |
| Trolitax<br>Pertinax<br>Ultrapas 'S' | Manila paper | | | Pollopas<br>Resopal<br>Ultrapas M | laminated |
| Dytron<br>Harex<br>Novotext | Hard fibre | | | Carda textile | |
| Lignofol<br>Pag wood | Synthetic resinmoulded resin | | | | |

**Duroplastics**
Hardenable synthetics

Gets hard and shiny when subjected to pressure and heat. Cannot be softened again on heating. Duroplastics can be machined under strain.

Trade names
Artificial horn, Galalith

Trade names
Vulcanfibre
Dynopas
Hornex

Trade names
Celluloid
Cellon
Ecarite
Trolite F
Celloph.
Crystal Glass-celluloid

Trade names
Mipolam
Trolitul
Trovidur
Astralon
Trolen
Vinidur
Plexiglass

**Thermoplastics**
Non-hardening synthetic materials

Can be softened on heating:
At 60 to 80 °C, soft and ductile. Thermoplastics can be welded and reshaped on heating

Trade mark shown at left engraved in a formed article indicates that the very item had been approved by the Federal Agency Material Testing Board (Berlin-Dahlem, W.-Germany).

31 = Phenoplastics moulding compounds with wood meal
NN = Manufacturer's symbol

Laminated Plastic
**Vulcanized fibre**
DIN 7737 (Sept. 59)

| Type | Bending strength $\sigma_{bB}$ N/mm² | Shock resistance $\alpha_K$ J/cm² | Tensile strength $\sigma_{zB}$ N/mm² | Compressive strength $\sigma_{dB}$ N/mm² | Characteristic properties | Examples of application |
|---|---|---|---|---|---|---|
| **Vf3110** | 90 | 8 | 65 | 150 | High tensile strength, can be well shaped, good electrical qualities, hardenable, high flexibility, special qualities for knobs, special flexibility and stretchability | For general purposes, dummy plugs and grips, in toothed wheels, sealing gaskets, knobs and suitcases |
| **Vf3120** | 90 | 8 | 65 | 150 | | |
| **Vf3130** | 90 | 9 | 70 | 180 | | |
| **Vf3140** | after agreement | | | | | |
| **Vf3150** | – | – | 55 | – | | |
| **Vf3160** | – | – | 60 | – | | |

Density: 1.2 to 1.5 g/cm³ Notation: VF3110 DIN 7737 Trade names: Dynapos, Gesalith

# Synthetic materials – Moulding compounds

Moulding compounds (pressure and jet-moulded compounds) = unshaped substances for manufacture of moulded parts or semi finished parts
Moulding plastics (pressure and jet-moulded plastics) = semi finished materials obtained from moulding compounds
Moulding parts (pressure and jet-moulded parts) = parts obtained from moulding compounds

| Synthetic materials Moulding compounds | Type | Filler material | Propert. derived fr. specimen piec. Bending strength $\sigma_{bB}$ | Impact strength at 20°C $a_n$ | Tensile strength $\sigma_B$ | Dimensional stability in heat (Martens) | Properties & Use / Trade names |
|---|---|---|---|---|---|---|---|
| **Duroplast moulding comp.** (harden. material) | | | N/mm² | J/cm² | N/mm² | °C | |
| **Phenoplast-moulded plastics** (Apr. 65) DIN 7708 (Okt. 68) | 11, 11.5 | Stone dust | 50 | 0.35 | 15 | 150 | High moisture (cable sleeves) |
| | 12 [1] | Asbestos fibre | 50 | 0.35 | 20 | 150 | & heat resistant parts e.g. |
| | 13, 13.5 | Mica | 50 | 0.30 | 20 | 150 | plugs, lamp holders, |
| | 15 [1] | Asbestos | 50 | 0.50 | 20 | 150 | sockets |
| | 16 | Asbestos cord | 70 | 1.50 | 25 | 150 | Can also be exp. at the same time to mech. loads<br>Toliten, Kerit, Alberit, Haveg |
| | 30, 30.5 | Wood dust | 60 | 0.50 | 25 | 100 | Electrical parts in automobiles, clamping plates |
| | 31, 31.5 [1] | Wood dust | 70 | 0.60 | 25 | 125 | multi-sided switches, radio cases |
| | 32 [1] | Wood dust | 70 | 0.60 | 25 | 125 | free of Ammonia |
| | 51, 51.5 | Paper fibres | 60 | 0.50 | 25 | 125 | Parts for high utility where type 31 |
| | 54 [1] | Paper scraps | 80 | 0.80 | 25 | 125 | does not suffice |
| | 57 | Paper sheets | 120 | 1.50 | 40 | 125 | Parts with very high strength |
| | 71 | Cotton | 60 | 0.60 | 25 | 125 | same as 51 |
| | 74, 74.5 | Cotton fibres, pieces | 60 | 1.20 | 25 | 125 | Highly rigid parts specially for bearing purposes |
| | 77 [1] | Cotton fabric, strips | 80 | 2.50 | 60 | 125 | Bearing material: Trolitan, Kenlitex, |
| | 83 | & wood dust | 60 | 0.50 | 25 | 125 | same as 51: Durax, Lignidur Isolit |
| **Ammonia-plast moulded plastics** DIN 7708 (Oct. 68) | 130-[1]5 | Wood dust | 70 | 0.60 | 25 | 100 | Temperature sensitive |
| | 131-[1]5 | Cellulose | 80 | 0.65 | 30 | 100 | |
| | 150 | Wood dust | 70 | 0.60 | 30 | 120 | Screw connections |
| | 152 | Cellulose | 80 | 0.70 | 30 | 120 | Insulating parts with high impact resistance, |
| | 153-5 | Cotton fibres | 60 | 0.50 | 40 | 125 | unbreakable crockery |
| | 155 [1] | Stone dust | 40 | 0.25 | 15 | 130 | Insulated parts with high heat resistance: Pollo-, Ultropas, Resopol, Biramin |
| | 156 | Asbestos fibres | 50 | 0.35 | 20 | 140 | |
| **Cold mould. plastics** | 212 | Stone dust | 40 | 0.20 | – | 150 | Processed by cold pressing |
| **Bituminous moulded plastics** DIN 7708 (Oct. 68) | 916 | Asbestos fibres | 40 | 0.35 | – | 65 | Processed by hot pressing |
| | 917 | Asbestos fibres | 25 | 0.15 | – | 65 | |
| **Thermoplastic jet-moulded materials** | | | | | with Vicat needle °C | | Humidity resistance, stable dimension, suitable for technical parts |
| **Polystyrol** DIN 7741 (Sept. 68) | 501 | no filler | 90 | 1.70 | – | 90 | Low current and high-frequency technique |
| | 502 | | 100 | 2.20 | – | 100 | Trolitul, Vestyron, Polystyrol |
| **Cellulose acetate abbreviated (CA-jet moulded materials** DIN 7742 (Aug. 59) | 431 | 50% acetate acid content, no filler, pigments added if necessary | 55 | 5.00 | – | 65 | High toughness, spraying of metals, frames of spectacles, combs, tool handles, not for parts to have exact dimensions as deformation takes place due to increase in humidity |
| | 432 | | 45 | 5.00 | – | 55 | |
| | 433 | | 38 | 5.00 | – | 50 | |
| | 434 | | 60 | 7.50 | – | 80 | |
| | 435 | | 48 | 6.50 | – | 65 | |
| | | | | | | | Trolitol, Cellidur, Ecaran, Hacoplast |
| **Cellulose acetobutyrate (CAB jet moulded materials)** DIN 7743 (May 59 x) | 411 | 40% butyric acid without filler, with pigments | 55 | 1.80 at 40°C $a_n$ | – | 100 | High strength, resistance to heat and weatherproof conditions. Door fittings, steering wheels, panels |
| | 412 | | 45 | 1.50 | – | 80 | |
| | 413 | | 38 | 1.20 | – | 70 | |
| | | | | | | | Celidur B, Tenite II |

Designation of the material (moulded plastics = FS) made in standardized conditions, from press materials Type 31
e.g. Rod 10 x 100 DIN ... FS 31

[1] 5 = high quality for electrical use

| Type | rough density p/cm³ |
|---|---|
| 11 ... 16 | 1.8 ... 2.0 |
| 30 ... 83 | 1.4 |
| 130 ... 153 | 1.5 |
| 155 | 2.0 |
| 156 | 1.8 |

# Laminated moulded materials

DIN 7735 (Oct. 65)

**Laminated paper** **Laminated fabric** **Laminated glass**

Moulded plastic material = Plastic material shaped by compression or jet-moulding
Laminated plastic material = Plastic materials using continuous laminated materials as fillers
Laminated paper (Hp) = Laminated plastic made of resin and paper
Laminated fabric (Hgw) = Laminated moulded material made of resin and fabric
Laminated glass (Hm) = Laminated moulded material made of resin and glass filament

Boards and strips measure standards: DIN 40605, DIN 40606)

| Type | Composition: Resin | Composition: Filler materials | Density g/cm³ | Bending strength N/mm² $\sigma_{bB}$ | Impact resist. J/cm² $a_n$ | Tensile strength N/mm² $\sigma_B$ | Compr. strength N/mm² $\sigma_{dB}$ |
|---|---|---|---|---|---|---|---|
| Hp 2061 | Phenol resin | Paper | 1.3–1.4 | 150 | 2 | 120 | 150 |
| Hgw 2072 | Phenol resin | Glass silk fabric | 1.6–1.8 | 200 | 5 | 100 | 150 |
| Hgw 2082 | Phenol resin | Fine cotton fabric | 1.3–1.4 | 130 | 3 | 80 | 170 |
| Hgw 2372 | Epoxy resin | Glass fabric | 1.7–1.9 | 340 | 10 | 220 | 200 |
| Hm 2472 | Polyester resin | Glass matte | 1.6–1.8 | 200 | 10 | 100 | 150 |
| Coiled tubes (Measure standards: DIN 40607) | | | | | | | |
| Hp 2066 | Phenol resin | Paper | ≧ 1.1 | 100 | – | – | 50 |
| Hgw 2085 | Phenol resin | Fine cotton fabric | 1.15–1.4 | 80 | – | 50 | 40 |
| Moulded tubes (Measure standards according to DIN 40615-40618 Solid rods (Measure standards: DIN 40624) Flat laths (Measure standards: DIN 40611) | | | | | | | |
| Hp 2068 | Phenol resin | Paper | 1.2–1.4 | 100 | 1.5 | 50 | 80 |
| Hgw 2088 | Phenol resin | Fine cotton fabric | 1.2–1.4 | 100 | 1.5 | 50 | 80 |

Pipes made of **PVC** hard (Polyvinylchloride hard) DIN 8062 (Jul. 72)
**PE** soft (Polyethelene soft) DIN 8072 (Apr. 71)
**PE** hard (Polyethelene hard) DIN 8074 (Aug. 70)

| Outer Ø d mm | PVC hard Series 2 | PVC hard Series 3 | PVC hard Series 4 | PVC hard Series 5 | PE soft Series 1 | PE soft Series 2 | PE soft Series 3 | PE hard Series 1 | PE hard Series 2 | PE hard Series 3 | PE hard Series 4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Wall thickness s in mm | | | | | | | | | | |
| 10 | – | – | – | 1.0 | – | – | 2.0 | – | – | – | |
| 12 | – | – | – | 1.0 | – | – | 2.0 | – | – | – | |
| 16 | – | – | – | 1.2 | – | 2.0 | 2.7 | – | – | – | |
| 20 | – | – | – | 1.5 | – | 2.2 | 3.4 | – | – | – | |
| 25 | – | – | 1.5 | 1.9 | 2.0 | 2.7 | 4.2 | – | – | – | 2.0 |
| 32 | – | – | 1.8 | 2.4 | 2.0 | 3.5 | 5.4 | – | – | – | 2.0 |
| 40 | – | 1.8 | 1.9 | 3.0 | 2.0 | 4.3 | 6.7 | – | – | 2.0 | 2.3 |
| 50 | – | 1.8 | 2.4 | 3.7 | 2.4 | 5.4 | 8.4 | – | – | 2.0 | 2.9 |
| 63 | – | 1.9 | 3.0 | 4.7 | 3.0 | 6.8 | 10.5 | – | 2.0 | 2.5 | 3.6 |
| 75 | 1.8 | 2.2 | 3.6 | 5.6 | 3.6 | 8.1 | 12.5 | 2.0 | 2.4 | 2.9 | 4.3 |
| 90 | 1.8 | 2.7 | 4.3 | 6.7 | 4.3 | 9.7 | 15.0 | 2.2 | 2.8 | 3.5 | 5.1 |
| 110 | 2.2 | 3.2 | 5.3 | 8.2 | 5.3 | 11.8 | 18.4 | 2.7 | 3.5 | 4.3 | 6.3 |
| 125 | 2.5 | 3.7 | 6.0 | 9.3 | 6.0 | 13.4 | 20.9 | 3.1 | 3.9 | 4.9 | 7.1 |
| 140 | 2.8 | 4.1 | 6.7 | 10.4 | 6.7 | – | – | 3.5 | 4.4 | 5.4 | 8.0 |
| 160 | 3.2 | 4.7 | 7.7 | 11.9 | 7.7 | – | – | 3.9 | 5.0 | 6.2 | 9.1 |
| 180 | 3.6 | 5.3 | 8.6 | 13.4 | – | – | – | 4.4 | 5.6 | 7.0 | 10.2 |
| 200 | 4.0 | 5.9 | 9.6 | 14.9 | – | – | – | 4.9 | 6.2 | 7.7 | 11.4 |
| 225 | 4.5 | 6.6 | 10.8 | 16.7 | – | – | – | 5.5 | 7.0 | 8.7 | 12.8 |

| Type of pipe | Operational pressure p in bar (for water upto 20 deg. C) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PVC hard | 4 | 6 | 10 | 16 | | | | | | | |
| PE | | | | | 2.5 | 6 | 10 | 2.5 | 3.2 | 4 | 6 |

**Density**

**PVC** hard 1.4 g/cm³
**PE** soft 0.92 g/cm³
**PE** hard 0.95 g/cm³

Wall thickness s and the operational pressure p have been obtained by the following equations

$$s = \frac{p \cdot d}{2\sigma + p}$$

$$p = \frac{2 \cdot s \cdot \sigma}{d - s}$$

For PVC 60 $\sigma = 6$ N/mm²

For PVC 100 $\sigma = 10$ N/mm²

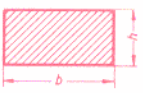
For PE soft $\sigma = 2.5$ N/mm²

For PE hard $\sigma = 5$ N/mm²

# Laminated moulded plastics products made of hard paper and fabric

Laminated paper DIN 40605 (7.67)
Laminated fabric DIN 40608 (4.59)

Flat-solid rod DIN 40627 (July 67)




Square solid rod DIN 40625 (7.67)

Hexagonal solid rod DIN 40626 (7.67)

Round solid rod DIN 40624 (7.67)

Moulded pipes DIN 40615 (7.67)

| Thickness | | Strips width | | width x height b · h | | a | | Wrench size a | d | | Outer d | Wall thickn. s |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.1 | 10 | 3 | 50 | 10x 5 | 28x20 | 4 | 50 | 10 | 3 | 40 | 5 | |
| 0.2 | 12 | 4 | 55 | 12x 6 | 30x10 | 5 | 60 | 14 | 4 | 45 | 6 | |
| 0.3 | 14 | 5 | 60 | 14x 6 | 30x16 | 6 | | 17 | 5 | 50 | 8 | |
| 0.4 | 16 | 6 | 70 | 15x 6 | 30x20 | 8 | | 22 | 6 | 55 | 10 | |
| 0.5 | 18 | 8 | 80 | 16x 6 | 34x10 | 10 | | 27 | 8 | 60 | 12 | 1 mm |
| 0.6 | 20 | 10 | 90 | 16x 8 | 34x16 | 12 | | 32 | 10 | 70 | 13 | and |
| 0.8 | 25 | 12 | 100 | 18x 6 | 34x20 | 14 | | 36 | 12 | 80 | 14 | 2 mm |
| 1 | 30 | 14 | 110 | 18x 8 | 36x16 | 16 | | 41 | 14 | | 16 | |
| 1.5 | 35 | 16 | 120 | 20x 6 | 36x20 | 18 | | 50 | 16 | | 18 | |
| 2 | 40 | 18 | 140 | 20x10 | 40x16 | 20 | | 60 | 18 | | 20 | |
| 2.5 | 45 | 20 | 160 | 20x16 | 40x20 | 22 | | | 20 | | 22 | |
| 3 | 50 | 22 | 180 | 24x10 | 50x20 | 24 | | | 22 | | 25 | |
| 3.5 | 60 | 25 | 200 | 24x16 | 60x20 | 26 | | | 25 | | 28 | |
| 4 | 70 | 28 | | 26x10 | 60x40 | 28 | | | 28 | | 30 | 2.5 mm |
| 4.5 | 80 | 30 | | 26x16 | 70x25 | 30 | | | 30 | | 32 | and |
| 5 | 90 | 35 | | 26x20 | 70x40 | 35 | | | 32 | | 40 | 5 mm |
| 6 | 100 | 40 | | 28x10 | | 40 | | | 35 | | 50 | |
| 8 | | 45 | | 28x16 | | 45 | | | 38 | | 60 | |

Material: Laminated paper and fabric according to DIN 7735 — Density ≈ 1.3 g/cm³

Description:

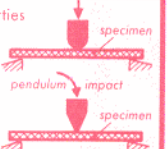
| | | | |
|---|---|---|---|
| Board 2 | DIN 40606 – Hgw 2082 – | Board 2, thick made laminated of fabric 2082 – | DIN 7735 |
| Fl 20 x 10 x 100 | DIN 40627 – Hp 2068 | flat solid bar 20 wide 10 thick, 100 long of laminated paper Hp 2068 | DIN 7735 |
| 4 kt 20 x 100 | DIN 40625 – Hp 2068 – | Square bar a = 20 mm. 100 length a. Hp. 2068– | DIN 7735 |
| 6 kt 22 x 100 | DIN 40626 – Hp 2068 | Hexagon bar, 22 mm flat made of laminated paper Hp 2068 | DIN 7735 |
| Rd 20 x 100 | DIN 40624 – Hp 2068 | Round bar 20 Ø 100 long of laminated paper | DIN 7735 |
| Pipe 20 x 2 x 100 | DIN 40615 – Hp 2068 | Pipe 20 outer Ø 2 mm wall thickness 100 long of Hp 2068 | DIN 7735 |

## Flexural strength — Ultimate bending stress — Impact toughness — Dimensional stability

The flexibility test serves to determine the strength and the shape changing properties

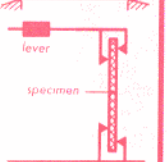
**Flexural strength** $\sigma_{bB}$ = Bending moment (as specimen reptures) [N mm] / Moment of resistance of the specimen [mm³]

**Ultimate bending stress** $\sigma_{bG}$ = Bending moment for fixed deflection [N mm] / Moment of resistance of the specimen [mm³]



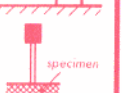

The impact bending test serves for the judgement of the brittleness and toughness

**Impact toughness** $a_n$ = Impact energy required by specimen (J) / Cross section of specimen [cm²]




The dimensional stability under heat is ascertaining according to Martins, in which a rod is loaded in bending and heated till the lever arm end sinks by a certain measure.

The dimensional stability under heat is ascertained using the Vicat needle test, in which a steel needle of 1 mm² cross section is placed on the surface of the specimen and a force of 50 N as test load is applied on it. The temperature in °C at which the needle penetrates the surface of the specimen by 1 mm is taken as parameter denoting dimensional stability.



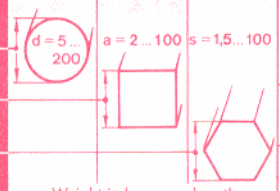
# Measure standards

## Dimensions and weights

**Round, square and hexagon steel rods, normal** — Density $\varrho = 7.85$ kg/dm³

Notation ⌀ 8 DIN 671 ST 37 — □ 30 DIN 178 St33 — ⬡ 32 DIN 176 - 9 S 20

Material: Types of steel as per DIN 17100, DIN 17200, DIN 17210 and DIN 1651




| | DIN 671 (May 59) | DIN 178 (June 69) | DIN 176 (Feb. 72) |
|---|---|---|---|
| | Weight in kg per m length | | |
| 5 | 0,154 | 0,196 | 0,170 |
| 6 | 0,222 | 0,283 | 0,245 |
| 7 | 0,302 | 0,385 | 0,333 |
| 8 | 0,395 | 0,502 | 0,435 |
| 9 | 0,499 | 0,636 | 0,551 |
| 10 | 0,617 | 0,785 | 0,680 |
| 11 | 0,746 | 0,950 | 0,823 |
| 12 | 0,888 | 1,13 | 0,979 |
| 14 | 1,21 | 1,54 | 1,33 |
| 16 | 1,58 | 2,01 | 1,74 |
| 18 | 2,00 | 2,54 | (17) ··· (1,96) |
| 20 | 2,47 | 3,14 | (19) ··· (2,45) |
| 22 | 2,98 | 3,80 | 3,29 |
| 25 | 3,85 | 4,91 | (24) ··· (3,92) |
| 28 | 4,83 | 6,15 | (27) ··· (4,96) |
| 32 | 6,31 | 8,04 | 6,96 |
| 36 | 7,99 | 10,2 | 8,81 |
| 40 | 9,86 | 12,6 | (41) ··· (11,4) |
| 45 | 12,5 | 15,9 | (46) ··· (14,4) |
| 50 | 15,4 | 19,6 | 17,0 |
| 56 | 19,3 | — | (55) ··· (20,6) |
| 63 | 24,5 | 31,2 | (65) ··· (28,7) |
| 70 | 30,2 | 38,5 | 33,3 |
| 80 | 39,5 | 50,2 | 43,5 |
| 90 | 49,5 | — | 55,1 |
| 100 | 61,7 | 78,5 | 68,0 |
| 125 | 96,3 | — | — |
| 140 | 121,0 | — | — |
| 160 | 158,0 | — | — |
| 180 | 200,0 | — | — |
| 200 | 247,0 | — | — |

**Flat steel** — DIN 174 (Jun. 69)

| Breadth b | Weight in kg per m length — Thickness h | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2 | 2,5 | 3 | 4 | 5 | 6 | 8 |
| 5 | 0,079 | 0,098 | 0,118 | — | — | — | — |
| 6 | 0,094 | 0,118 | 0,141 | 0,188 | — | — | — |
| 8 | 0,126 | 0,157 | 0,188 | 0,251 | 0,314 | 0,377 | — |
| 10 | 0,157 | 0,196 | 0,236 | 0,314 | 0,393 | 0,471 | — |
| 12 | 0,188 | 0,236 | 0,283 | 0,377 | 0,471 | 0,565 | 0,754 |
| 14 | 0,220 | 0,275 | 0,330 | 0,440 | 0,550 | 0,659 | 0,879 |
| 16 | 0,251 | 0,314 | 0,377 | 0,502 | 0,628 | 0,754 | 1,00 |
| 18 | 0,283 | 0,354 | 0,424 | 0,565 | 0,707 | 0,848 | 1,13 |
| 20 | 0,314 | 0,393 | 0,471 | 0,628 | 0,785 | 0,942 | 1,26 |

| Breadth b | 3 | 4 | 5 | 6 | 8 | 10 | 12 |
|---|---|---|---|---|---|---|---|
| 22 | 0,518 | 0,691 | 0,864 | 1,04 | 1,38 | 1,73 | 2,07 |
| 25 | 0,589 | 0,785 | 0,981 | 1,18 | 1,57 | 1,96 | 2,36 |
| 28 | 0,659 | 0,879 | 1,10 | 1,32 | 1,76 | 2,20 | 2,64 |
| 32 | 0,754 | 1,00 | 1,26 | 1,51 | 2,01 | 2,51 | — |
| 36 | 0,848 | 1,13 | 1,41 | 1,70 | — | 2,83 | 3,39 |
| 40 | 0,942 | 1,26 | 1,57 | 1,88 | 2,51 | 3,14 | 3,77 |
| 45 | 1,06 | 1,41 | 1,77 | 2,12 | 2,83 | 3,53 | — |
| 50 | 1,18 | 1,57 | 1,96 | 2,36 | 3,14 | 3,93 | 4,71 |

| Breadth b | 5 | 6 | 10 | 12 | 16 | 20 | 25 |
|---|---|---|---|---|---|---|---|
| 56 | 2,20 | — | 4,40 | 5,28 | 7,03 | 8,79 | 11,0 |
| 63 | 2,47 | 2,97 | 4,95 | 5,93 | 7,91 | 9,89 | 12,4 |
| 70 | 2,75 | 3,30 | 5,50 | 6,59 | 8,79 | 11,0 | 13,7 |
| 80 | 3,14 | 3,77 | 6,28 | 7,54 | 10,0 | 12,6 | 15,7 |
| 90 | 3,53 | 4,24 | 7,07 | 8,48 | 11,3 | 14,1 | 17,7 |
| 100 | 3,93 | 4,71 | 7,85 | 9,42 | 12,6 | 15,7 | 19,6 |
| 125 | 4,91 | 5,89 | 9,81 | 11,8 | 15,7 | 19,6 | 24,5 |
| 140 | — | 6,59 | 11,0 | 13,2 | — | — | — |
| 160 | — | — | 12,6 | — | — | 25,1 | 31,4 |
| 180 | — | — | 14,1 | — | — | 28,3 | 35,3 |
| 200 | — | — | 15,7 | — | — | 31,4 | 39,3 |

Weight of other materials. The values in the above tables must be multiplied by the following numerals:

Grey cast iron by 0.924 — Brass by 1.083 — Aluminium by 0.344

Copper by 1.134 — Red casting by 1.096 — Aluminium alloy by 0.357

**Measuring standards for normal circular steel**

| | | | Materials | Examples of the notations |
|---|---|---|---|---|
| Polarized round steel | h 9 | DIN 175 (May 59) | Tool steel, high speed steel | ⌀ 4 DIN 175 C 110 W1 |
| Normal round steel | h 8 | DIN 670 (May 59) | preferably made of quality steel according to DIN 1652 & DIN 1651 | ⌀ 20 DIN 670 St 37 K |
| Normal round steel | h 9 | DIN 671 (May 59) | | ⌀ 40 DIN 671 C 35 K |
| Normal round steel | h 11 | DIN 669 (May 59) | | ⌀ 20 DIN 668 St 37 K |
| Normal steel shaft | h 9 | DIN 669 (May 59) | (⌀ 5 ... 200) | Shaft 50 DIN 669 St 50 K |

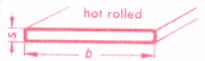
Preferable diameter to use as follows

1 1.2 1.4 1.6 1.8 2. 2.2 2.5 2.8 3 3.5 4 4.5 5 6 6.3 7 8 9 10 11 12 14 16

18 20 22 25 28 32 36 40 45 50 56 63 80 90 100 125 140 160 180 200

## Band steel

DIN 1016 (Nov. 72)




Nomenclature of band steel of 50 mm width, 12 mm thickness of St. 33

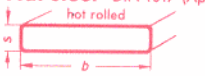
Bd 50 x 2 DIN 1016-St 33
Bd 50 x 2-R 600 DIN 1016-St 33 (rolled rings of 600 mm inner Ø)
Bd 50 x 2-B 2300 DIN 1016 St 33 (Bundle with 2300 mm inner length)
Bd 50 x 2 x 2500 DIN 1016-St 33 (Strips with 2500 mm length)
□ 50 x 2 x 2500 DIN 1016-St 33

Density: $\varrho = 7.85$ kg/dm³ Material: Steel acc. to DIN 17100 Supplied as: bundles, rings or strips upto 500 mm breath

| Breadth b mm | Thickness s in mm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0,8 | 1 | 1,5 | 2 | 2,5 | 3 | 3,5 | 4 | 5 |
| | Weight in kg/m | | | | | | | | |
| 10 | — | — | 0,118 | 0,157 | 0,196 | 0,236 | 0,275 | — | — |
| 12 | — | 0,0942 | 0,141 | 0,188 | 0,236 | 0,283 | 0,329 | 0,377 | — |
| 14 | — | 0,110 | 0,165 | 0,220 | 0,275 | 0,330 | 0,385 | 0,439 | — |
| 16 | — | 0,126 | 0,188 | 0,251 | 0,314 | 0,377 | 0,440 | 0,502 | 0,628 |
| 18 | — | 0,141 | 0,212 | 0,283 | 0,353 | 0,424 | 0,495 | 0,565 | 0,707 |
| 20 | 0,126 | 0,157 | 0,236 | 0,314 | 0,393 | 0,471 | 0,550 | 0,628 | 0,785 |
| 22 | 0,138 | 0,173 | 0,259 | 0,345 | 0,432 | 0,518 | 0,604 | 0,691 | 0,864 |
| 25 | 0,157 | 0,196 | 0,294 | 0,393 | 0,491 | 0,589 | 0,687 | 0,785 | 0,981 |
| 30 | 0,188 | 0,236 | 0,353 | 0,471 | 0,589 | 0,707 | 0,824 | 0,942 | 1,18 |
| 32 | 0,201 | 0,251 | 0,377 | 0,502 | 0,628 | 0,754 | 0,879 | 1,00 | 1,26 |
| 35 | 0,220 | 0,275 | 0,412 | 0,550 | 0,687 | 0,824 | 0,962 | 1,10 | 1,37 |
| 40 | 0,251 | 0,314 | 0,471 | 0,628 | 0,785 | 0,942 | 1,10 | 1,26 | 1,57 |
| 45 | 0,283 | 0,353 | 0,530 | 0,707 | 0,883 | 1,06 | 1,24 | 1,41 | 1,77 |
| 50 | 0,314 | 0,392 | 0,589 | 0,785 | 0,981 | 1,18 | 1,37 | 1,57 | 1,96 |
| 55 | 0,345 | 0,471 | 0,648 | 0,864 | 1,08 | 1,30 | 1,51 | 1,73 | 2,16 |

## Flat steel

DIN 1017 (Apr. 67)




Nomenclature for flat steel with 40 mm width, 12 mm thickness of St. 37

Flat steel 40 x 12 DIN 1017-St 37
or Flat 40 x 12 DIN 1017-St 37
or Fl 40 x 12 DIN 1017-St 37

Density: $\varrho = 7.85$ kg/dm³ Materials (to be supplied by placing the order) Types of steel as per DIN 17100, DIN 17200, DIN 17210, and DIN 1651

| Breadth b mm | Thickness s in mm | | | | | | |
|---|---|---|---|---|---|---|---|
| | 5 | 6 | 6,5 | 7 | 8 | 9 | 10 |
| | Weight in kg/m | | | | | | |
| 10 | 0,393 | — | — | — | — | — | — |
| 11 | 0,432 | 0,518 | — | — | — | — | — |
| 12 | 0,471 | 0,565 | — | — | — | — | — |
| 13 | 0,510 | 0,612 | 0,663 | 0,714 | 0,816 | — | — |
| 14 | 0,550 | 0,659 | — | 0,769 | 0,879 | — | — |
| 15 | 0,589 | 0,707 | — | 0,824 | 0,942 | — | 1,18 |
| 16 | 0,628 | 0,754 | 0,816 | 0,879 | 1,00 | 1,13 | 1,26 |
| 17 | 0,667 | 0,801 | 0,867 | 0,934 | 1,07 | 1,20 | 1,33 |
| 18 | 0,707 | 0,848 | 0,918 | 0,989 | 1,13 | 1,27 | 1,41 |
| 19 | 0,746 | 0,895 | 0,969 | 1,04 | 1,19 | 1,34 | 1,49 |
| 20 | 0,785 | 0,942 | 1,02 | 1,10 | 1,26 | 1,41 | 1,57 |
| 22 | 0,864 | 1,04 | 1,12 | 1,21 | 1,38 | — | 1,73 |
| 25 | 0,981 | 1,18 | 1,28 | 1,37 | 1,57 | — | 1,96 |
| 26 | 1,02 | 1,22 | 1,33 | 1,43 | 1,63 | — | 2,04 |
| 28 | 1,10 | 1,32 | 1,43 | 1,54 | 1,76 | — | 2,20 |
| 30 | 1,18 | 1,41 | 1,53 | 1,65 | 1,88 | 2,12 | 2,36 |
| 32 | 1,26 | 1,51 | 1,63 | — | 2,01 | — | 2,51 |
| 35 | 1,37 | 1,65 | 1,79 | 1,92 | 2,20 | — | 2,75 |
| 38 | 1,49 | 1,79 | 1,94 | — | 2,39 | — | 2,98 |
| 40 | 1,57 | 1,88 | 2,04 | 2,20 | 2,51 | 2,83 | 3,14 |
| 45 | 1,77 | 2,12 | 2,30 | 2,47 | 2,83 | — | 3,53 |
| 50 | 1,96 | 2,36 | 2,55 | 2,75 | 3,14 | 3,53 | 3,93 |

These standards are applicable for hot rolled flat steel 10 x 5 to 150 x 60 mm² cross section.
Flat steel upto 1.69 cm² cross section would in reels like watch springs are classified as band steel.

| Breadth b mm | Thickness s in mm | | | | | | |
|---|---|---|---|---|---|---|---|
| | 11 | 12 | 13 | 14 | 15 | 16 | 18 |
| | Weight in kg/m | | | | | | |
| 18 | 1,55 | — | — | — | — | — | — |
| 19 | 1,64 | 1,79 | — | — | — | — | — |
| 20 | 1,73 | 1,88 | 2,04 | — | 2,36 | — | — |
| 22 | 1,90 | 2,07 | 2,25 | 2,42 | 2,59 | — | — |
| 25 | — | 2,36 | 2,55 | 2,75 | 2,94 | 3,14 | — |
| 26 | — | 2,45 | 2,65 | 2,86 | 3,06 | 3,27 | 3,67 |
| 28 | — | 2,64 | 2,86 | 3,08 | 3,30 | 3,52 | 3,96 |
| 30 | — | 2,83 | 3,06 | 3,30 | 3,53 | 3,77 | 4,24 |
| 32 | — | 3,01 | 3,27 | 3,52 | 3,77 | 4,02 | — |
| 35 | — | 3,30 | 3,57 | 3,85 | 4,12 | 4,40 | — |
| 38 | — | 3,58 | 3,88 | 4,18 | 4,47 | 4,77 | — |
| 40 | — | 3,77 | 4,08 | 4,40 | 4,71 | 5,02 | 5,65 |
| 45 | — | 4,24 | 4,59 | 4,95 | 5,30 | 5,65 | — |
| 50 | — | 4,71 | 5,10 | 5,50 | 5,89 | 6,28 | 7,07 |

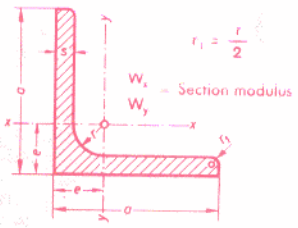
**Hot rolled wide flat steel** according to DIN 59 200 (Sep. 59). Material: Structural steels according to DIN 17 100:

Thickness: 5 6 7 8 9 10 12 13 14 15 16 18 20 22 24 26 28 30 35 40 45 50
Breadth: 151 160 180 190 200 210 230 240 250 275 300 325 350 375 400 425 450 to 1250

Nomenclature of a hot rolled wide flat steel which is 200 mm wide and 10 mm thick made of St 37 according to DIN 17100: Wide flat steel 200 x 10 DIN 59 200 St 37
or □ 200 x 10 DIN 59 200 St 37 or Br Fl 200 x 10 DIN 59 200 St 37

## Equal sided L-Steel

DIN 1028 (x Jun. 67)

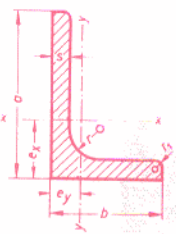



Nomenclature for equal sided L-steel of 50 mm leg breadth and 5 mm leg thickness made of .... (material: Steel according to DIN 17100)

L 50 x 5 DIN 1028 St...

## Unequal sided L-steel

DIN 1029 (x Jun. 67)




Nomenclature for unequal sided L-steel with 65 and 50 mm leg breadth and 5 mm thickness made of .... (material: Steel according to DIN 17100)

L 65 x 50 x 5 DIN 1029 St...

| Symbol L a s | r | Cross section | Weight | e | $W_{x(y)}$ | Symbol L a b s | r | Cross section | Weight | Distances from the axis | | Section moduli | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| mm | mm | $cm^2$ | kg/m | cm | $cm^3$ | mm | mm | $cm^2$ | kg/m | $e_x$ cm | $e_y$ cm | $W_x$ $cm^3$ | $W_y$ $cm^3$ |
| 20x3 | 3,5 | 1,12 | 0,88 | 0,6 | 0,28 | 30x20x3 | 3,5 | 1,42 | 1,11 | 0,99 | 0,50 | 0,62 | 0,29 |
| 20x4 | 3,5 | 1,45 | 1,14 | 0,64 | 0,35 | 30x20x4 | 3,5 | 1,85 | 1,45 | 1,03 | 0,54 | 0,81 | 0,38 |
| 25x3 | 3,5 | 1,42 | 1,12 | 0,73 | 0,45 | 40x20x3 | 3,5 | 1,72 | 1,35 | 1,43 | 0,44 | 1,08 | 0,30 |
| 25x4 | 3,5 | 1,85 | 1,45 | 0,76 | 0,58 | 40x20x4 | 3,5 | 2,25 | 1,77 | 1,47 | 0,48 | 1,42 | 0,39 |
| 25x5 | 3,5 | 2,26 | 1,77 | 0,80 | 0,69 | 45x30x3 | 4,5 | 2,19 | 1,72 | 1,43 | 0,70 | 1,46 | 0,70 |
| 30x3 | 5 | 1,74 | 1,36 | 0,84 | 0,65 | 45x30x4 | 4,5 | 2,87 | 2,25 | 1,48 | 0,74 | 1,91 | 0,91 |
| 30x4 | 5 | 2,27 | 1,78 | 0,89 | 0,86 | 45x30x5 | 4,5 | 3,53 | 2,77 | 1,52 | 0,78 | 2,35 | 1,11 |
| 30x5 | 5 | 2,78 | 2,18 | 0,92 | 1,04 | 50x40x4 | 4 | 3,46 | 2,71 | 1,52 | 1,03 | 2,47 | 1,64 |
| 35x3 | 5 | 3,27 | 2,56 | 0,96 | 0,90 | 50x40x5 | 4 | 4,27 | 3,35 | 1,56 | 1,07 | 3,02 | 2,01 |
| 35x4 | 5 | 2,67 | 2,10 | 1,00 | 1,18 | 60x30x5 | 6 | 4,29 | 3,37 | 2,15 | 0,68 | 4,04 | 1,12 |
| 35x5 | 5 | 3,28 | 2,57 | 1,04 | 1,45 | 60x30x7 | 6 | 5,85 | 4,59 | 2,24 | 0,76 | 5,50 | 1,52 |
| 35x6 | 5 | 3,87 | 3,04 | 1,08 | 1,71 | 60x40x5 | 6 | 4,79 | 3,76 | 1,96 | 0,97 | 4,25 | 2,02 |
| 40x3 | 6 | 2,35 | 1,84 | 1,07 | 1,18 | 60x40x6 | 6 | 5,68 | 4,46 | 2,00 | 1,01 | 5,03 | 2,38 |
| 40x4 | 6 | 3,08 | 2,42 | 1,12 | 1,56 | 60x40x7 | 6 | 6,55 | 5,14 | 2,04 | 1,05 | 5,79 | 2,74 |
| 40x5 | 6 | 3,79 | 2,97 | 1,16 | 1,91 | 65x50x5 | 6,5 | 5,54 | 4,35 | 1,99 | 1,25 | 5,11 | 3,18 |
| 40x6 | 6 | 4,48 | 3,52 | 1,20 | 2,26 | 65x50x7 | 6,5 | 7,60 | 5,97 | 2,07 | 1,33 | 6,99 | 4,31 |
| 45x4 | 7 | 3,49 | 2,74 | 1,23 | 1,97 | 65x50x9 | 6,5 | 9,58 | 7,52 | 2,15 | 1,41 | 8,77 | 5,39 |
| 45x5 | 7 | 4,30 | 3,38 | 1,28 | 2,43 | 75x50x5 | 6,5 | 6,04 | 4,74 | 2,40 | 1,17 | 6,74 | 3,21 |
| 45x6 | 7 | 5,09 | 4,00 | 1,32 | 2,88 | 75x50x7 | 6,5 | 8,30 | 6,51 | 2,48 | 1,25 | 9,24 | 4,39 |
| 45x7 | 7 | 5,86 | 4,60 | 1,36 | 3,31 | 75x50x9 | 6,5 | 10,5 | 8,23 | 2,56 | 1,32 | 11,6 | 5,49 |
| 50x4 | 7 | 3,89 | 3,06 | 1,36 | 2,46 | 75x55x5 | 7 | 6,30 | 4,95 | 2,31 | 1,33 | 6,84 | 3,89 |
| 50x5 | 7 | 4,80 | 3,77 | 1,40 | 3,05 | 75x55x7 | 7 | 8,66 | 6,80 | 2,40 | 1,41 | 9,39 | 5,32 |
| 50x6 | 7 | 5,69 | 4,47 | 1,45 | 3,61 | 75x55x8 | 7 | 9,81 | 7,70 | 2,43 | 1,45 | 10,6 | 6,00 |
| 50x7 | 7 | 6,56 | 5,15 | 1,49 | 4,15 | 75x55x9 | 7 | 10,9 | 8,59 | 2,47 | 1,48 | 11,8 | 6,66 |
| 50x8 | 7 | 7,41 | 5,82 | 1,52 | 4,68 | 80x40x6 | 7 | 6,89 | 5,41 | 2,85 | 0,88 | 8,73 | 2,44 |
| 50x9 | 7 | 8,24 | 6,47 | 1,56 | 5,20 | 80x40x8 | 7 | 9,01 | 7,07 | 2,94 | 0,95 | 11,4 | 3,18 |
| 55x5 | 8 | 5,32 | 4,18 | 1,52 | 3,70 | 80x65x6 | 8 | 8,41 | 6,60 | 2,39 | 1,65 | 9,41 | 6,44 |
| 55x6 | 8 | 6,31 | 4,95 | 1,56 | 4,40 | 80x65x8 | 8 | 11,0 | 8,66 | 2,47 | 1,73 | 12,3 | 8,41 |
| 55x8 | 8 | 8,23 | 6,46 | 1,64 | 5,72 | 80x65x10 | 8 | 13,6 | 10,7 | 2,55 | 1,81 | 15,1 | 10,3 |
| 55x10 | 8 | 10,1 | 7,90 | 1,72 | 6,97 | 90x60x6 | 7 | 8,69 | 6,82 | 2,89 | 1,41 | 11,7 | 5,61 |
| 60x5 | 8 | 5,82 | 4,57 | 1,64 | 4,45 | 90x60x8 | 7 | 11,4 | 8,96 | 2,97 | 1,49 | 15,4 | 7,31 |
| 60x6 | 8 | 6,91 | 5,42 | 1,69 | 5,29 | 100x50x6 | 9 | 8,73 | 6,85 | 3,49 | 1,04 | 13,8 | 3,86 |
| 60x8 | 8 | 9,03 | 7,09 | 1,77 | 6,88 | 100x50x8 | 9 | 11,5 | 8,99 | 3,59 | 1,13 | 18,0 | 5,04 |

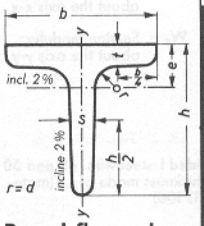
Gauge dimensions for L-steel — DIN 998 (Oct. 70) DIN 999 (Oct. 70)

| Leg length | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 90 | 100 | 110 | 120 | 130 | 140 | 150 | 160 | 180 | 200 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rivet hole Ø | 8,4 | 11 | 11 | 13 | 13 | 17 | 17 | 21 | 21 | 23 | 23 | 25 | 25 | 25 | 25 | 25 | 28 | 28 | 28 | 28 | 28 |
| $w_1$ | 17 | 18 | 22 | 25 | 30 | 30 | 35 | 35 | 40 | 40 | 45 | 50 | 55 | 45 | 50 | 50 | 55 | 50 | 60 | 60 | 65 |
| $w_2$ | | | | | | | | | | | | | | 70 | 80 | 90 | 95 | 105 | 115 | 135 | 150 |

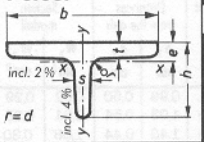
## T-steel

DIN 1024 (Oct. 63)

### Deep-legged T-steel



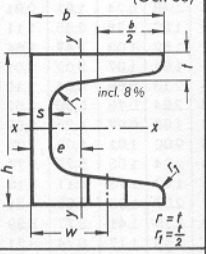

### Broad-flanged T-steel




| Symbol | Dimensions in mm for | | | | Cross section | Weight (7.85 kg/dm³) | Distance | Section modulus for the bending axis x-x | Section modulus for the bending axis y-y | DIN 997 (Oct. 70) Gauge dimension: Rivet-hole | w | $w_1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | T | | e | $W_x$ | $W_y$ | | | |
| T | h | b | s | t | cm² | kg/m | cm | cm³ | cm³ | ϕ | w | $w_1$ |
| 20 | 20 | 20 | 3 | 3 | 1,12 | 0,88 | 0,58 | 0,27 | 0,20 | | | |
| 25 | 25 | 25 | 3,5 | 3,5 | 1,64 | 1,29 | 0,73 | 0,49 | 0,34 | 3,2 | 15 | 14 |
| 30 | 30 | 30 | 4 | 4 | 2,26 | 1,77 | 0,85 | 0,80 | 0,58 | 4,3 | 17 | 17 |
| 35 | 35 | 35 | 4,5 | 4,5 | 2,97 | 2,33 | 0,99 | 1,23 | 0,90 | 4,3 | 19 | 19 |
| 40 | 40 | 40 | 5 | 5 | 3,77 | 2,96 | 1,12 | 1,84 | 1,29 | 6,4 | 21 | 22 |
| 45 | 45 | 45 | 5,5 | 5,5 | 4,67 | 3,67 | 1,26 | 2,51 | 1,78 | 6,4 | 24 | 25 |
| 50 | 50 | 50 | 6 | 6 | 5,66 | 4,44 | 1,39 | 3,36 | 2,42 | 6,4 | 30 | 30 |
| 60 | 60 | 60 | 7 | 7 | 7,94 | 6,23 | 1,66 | 5,48 | 4,07 | 8,4 | 34 | 35 |
| 70 | 70 | 70 | 8 | 8 | 10,6 | 8,32 | 1,94 | 8,79 | 6,32 | 11 | 38 | 40 |
| 80 | 80 | 80 | 9 | 9 | 13,6 | 10,7 | 2,22 | 12,8 | 9,25 | 11 | 45 | 45 |
| 90 | 90 | 90 | 10 | 10 | 17,1 | 13,4 | 2,48 | 18,2 | 13,0 | 13 | 50 | 50 |
| 100 | 100 | 100 | 11 | 11 | 20,9 | 16,4 | 2,74 | 24,6 | 17,7 | 13 | 60 | 60 |
| TB | | | | | | | | | | | | |
| 30 | 30 | 60 | 5,5 | 5,5 | 4,64 | 3,64 | 0,67 | 1,11 | 2,87 | 8,4 | 34 | — |
| 35 | 35 | 70 | 6 | 6 | 5,94 | 4,66 | 0,77 | 1,65 | 4.31 | 11 | 37 | — |
| 40 | 40 | 80 | 7 | 7 | 7,91 | 6,21 | 0,88 | 2,50 | 7,13 | 11 | 45 | — |
| 50 | 50 | 100 | 8,5 | 8,5 | 12,0 | 9,42 | 1,09 | 4,78 | 13,5 | 13 | 55 | — |
| 60 | 60 | 120 | 10 | 10 | 17,0 | 13,4 | 1,30 | 8,09 | 22,8 | 17 | 65 | — |

## ⊏-steel

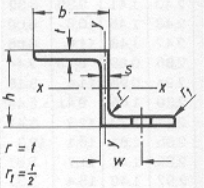
DIN 1026 (Oct. 63)




| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ⊏ | | | | | | | | | | | | |
| 30 x 15 | 30 | 15 | 4 | 4,5 | 2,21 | 1,74 | 0,52 | 1,69 | 0,39 | | | |
| 30 | 30 | 33 | 5 | 7 | 5,44 | 4,27 | 1,31 | 4,26 | 2,68 | | | |
| 40 x 20 | 40 | 20 | 5 | 5 | 3,51 | 2,75 | 0,65 | 3,63 | 0,78 | | | |
| 40 | 40 | 35 | 5 | 7 | 6,21 | 4,87 | 1,33 | 7,05 | 3,08 | 8,4 | 20 | |
| 50 x 25 | 50 | 25 | 6 | 6,5 | 5,50 | 4,32 | 0,82 | 7,18 | 1,75 | 8,4 | 16 | |
| 50 | 50 | 38 | 5 | 7 | 7,12 | 5,59 | 1,37 | 10,6 | 3,75 | 11 | 20 | |
| 60 | 60 | 30 | 6 | 6 | 6,46 | 5,07 | 0,91 | 10,5 | 2,16 | 8,4 | 18 | |
| 65 | 65 | 42 | 5,5 | 7,5 | 9,03 | 7,09 | 1,42 | 17,7 | 5,07 | 11 | 25 | |
| 80 | 80 | 45 | 6 | 8 | 11,0 | 8,64 | 1,45 | 26,5 | 6,36 | 13 | 25 | |
| 100 | 100 | 50 | 6 | 8,5 | 13,5 | 10,6 | 1,55 | 41,2 | 8,49 | 13 | 30 | |
| 120 | 120 | 55 | 7 | 9 | 17,0 | 13,4 | 1,60 | 60,7 | 11,1 | 17 | 30 | |
| 140 | 140 | 60 | 7 | 10 | 20,4 | 16,0 | 1,75 | 86,4 | 14,8 | 17 | 35 | |

## ⌞-steel

DIN 1027 (Oct. 63)




| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ⌞ | | | | | | | | | | | | |
| 30 | 30 | 38 | 4 | 4,5 | 4,32 | 3,39 | | 3,97 | 3,80 | | | |
| 40 | 40 | 40 | 4,5 | 5 | 5,43 | 4,26 | | 6,75 | 4,66 | 11 | 22 | |
| 50 | 50 | 43 | 5 | 5,5 | 6,77 | 5,31 | | 10,5 | 5,88 | 11 | 25 | |
| 60 | 60 | 45 | 5 | 6 | 7,91 | 6,21 | | 14,9 | 7,09 | 13 | 25 | |
| 80 | 80 | 50 | 6 | 7 | 11,1 | 8,71 | | 27,3 | 10,1 | 13 | 30 | |
| 100 | 100 | 55 | 6,5 | 8 | 14,5 | 11,4 | | 44,4 | 14,0 | 17 | 30 | |
| 120 | 120 | 60 | 7 | 9 | 18,2 | 14,3 | | 67,0 | 18,8 | 17 | 35 | |
| 140 | 140 | 65 | 8 | 10 | 22,9 | 18,0 | | 96,6 | 24,3 | 17 | 35 | |
| 160 | 160 | 70 | 8,5 | 11 | 27,5 | 21,6 | | 132 | 31,0 | 21 | 35 | |
| 180 | 180 | 75 | 9,5 | 12 | 33,3 | 26,1 | | 178 | 38,4 | 23 | 40 | |
| 200 | 200 | 80 | 10 | 13 | 38,7 | 30,4 | | 230 | 47,6 | 23 | 45 | |

Nomenclatures:

Deep legged T-steel with a height of h = 80 mm made of St. 33: T 80 DIN 1024 St 33
T-steel with a height h = 50 mm made of St 37: t TB 50 DIN 1024 St 37
⊏-Steel with a height of h = 120 mm made of St 33 acc. to DIN 17100: U 120 DIN 1026 St 33 or ⊏-120 DIN 1026 St 33
Z-steel with a height of h = 100 mm made of St 33 acc. to DIN 17100: Z-100 DIN 1027 St 33 or ⌞100 DIN 1027 St 33

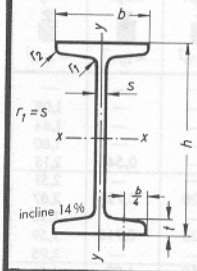
Material: Types of steel according to DIN 17100

## I-beam

DIN 1025 (May 63)

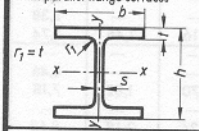
Material according to DIN 17 100

### Narrow I-beam



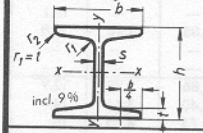

### Broad I-beam

with parallel flange surfaces



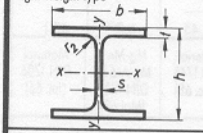

### Broad I-beam

With inclined flange surfaces



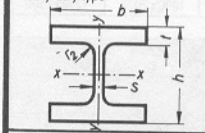

### Broad I-beam

light weight type

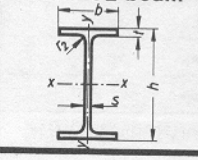



### Broad I-beam

heavy duty type




### Med. size I-beam




| Symbol | Dimensions in mm for h | b | s | t | $r_2$ | Cross section A $cm^2$ | Weight (7.85 kg/dm³) kg/m | Section modulus for the bending axis x-x $W_x$ $cm^3$ | y-y $W_y$ $cm^3$ | DIN 997 (Oct. 70) Gauge dimension W Rivet-hole $\phi$ | w |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **I** | | | | | | | | | | | |
| 80 | 80 | 42 | 3,9 | 5,9 | 2,3 | 7,58 | 5,95 | 19,5 | 3,00 | 6,4 | 22 |
| 100 | 100 | 50 | 4,5 | 6,8 | 2,7 | 10,6 | 8,32 | 34,2 | 4,88 | 6,4 | 28 |
| 120 | 120 | 58 | 5,1 | 7,7 | 3,1 | 14,2 | 11,2 | 54,7 | 7,41 | 8,4 | 32 |
| 140 | 140 | 66 | 5,7 | 8,6 | 3,4 | 18,3 | 14,4 | 81,9 | 10,7 | 11 | 34 |
| 160 | 160 | 74 | 6,3 | 9,5 | 3,8 | 22,8 | 17,9 | 117 | 14,8 | 11 | 40 |
| 180 | 180 | 82 | 6,9 | 10,4 | 4,1 | 27,9 | 21,9 | 161 | 19,8 | 13 | 44 |
| 200 | 200 | 90 | 7,5 | 11,3 | 4,5 | 33,5 | 26,3 | 214 | 26,0 | 13 | 48 |
| 220 | 220 | 98 | 8,1 | 12,2 | 4,9 | 39,6 | 31,1 | 278 | 33,1 | 13 | 52 |
| 240 | 240 | 106 | 8,7 | 13,1 | 5,2 | 46,1 | 36,2 | 354 | 41,7 | 17 | 56 |
| 260 | 260 | 113 | 9,4 | 14,1 | 5,6 | 53,4 | 41,9 | 442 | 51,0 | 17 | 60 |
| **I PB** | | | | | | | | | | | |
| 100 | 100 | 100 | 6,5 | 10 | – | 26,1 | 20,5 | 89,3 | 33,4 | 13 | 56 |
| 120 | 120 | 120 | 7 | 11 | – | 34,3 | 26,9 | 144 | 52,9 | 17 | 66 |
| 140 | 140 | 140 | 8 | 12 | – | 44,1 | 34,6 | 217 | 78,6 | 21 | 76 |
| 160 | 160 | 160 | 9 | 14 | – | 58,4 | 45,8 | 329 | 120 | 23 | 86 |
| 180 | 180 | 180 | 9 | 14 | – | 65,8 | 51,6 | 426 | 151 | 25 | 100 |
| 200 | 200 | 200 | 10 | 16 | – | 82,7 | 64,9 | 595 | 214 | 25 | 110 |
| **I B** | | | | | | | | | | | |
| 100 | 100 | 100 | 7,5 | 10,25 | 1,5 | 26,8 | 21,0 | 89,4 | 30,1 | 13 | 56 |
| 120 | 120 | 120 | 8 | 11 | 1,5 | 34,6 | 27,2 | 142 | 46,0 | 17 | 66 |
| 140 | 140 | 140 | 8 | 12 | – | 43,3 | 34,0 | 213 | 67,8 | 21 | 76 |
| 160 | 160 | 160 | 9 | 14 | – | 57,4 | 45,0 | 322 | 104 | 23 | 86 |
| 180 | 180 | 180 | 9 | 14 | – | 64,7 | 50,8 | 417 | 130 | 25 | 100 |
| **I PBl** | | | | | | | | | | | |
| 100 | 96 | 99 | 5,0 | 8,0 | 11 | 20,9 | 16,4 | 71,6 | 26,2 | 13 | 56 |
| 120 | 114 | 119 | 5,0 | 8,0 | 11 | 25,0 | 19,6 | 105 | 38,0 | 17 | 66 |
| 140 | 133 | 138 | 5,5 | 8,5 | 12 | 31,1 | 24,4 | 153 | 54,0 | 21 | 76 |
| 160 | 150 | 157 | 6,0 | 9,0 | 14 | 37,9 | 29,7 | 212 | 75,0 | 23 | 86 |
| 180 | 172 | 177 | 6,5 | 10,0 | 14 | 47,0 | 36,9 | 303 | 104 | 25 | 100 |
| 200 | 190 | 197 | 7 | 11,0 | 15 | 57,0 | 44,8 | 408 | 143 | 25 | 110 |
| **IPBv** | | | | | | | | | | | |
| 100 | 114 | 103,5 | 10 | 17 | 11 | 44,2 | 34,7 | 157 | 61 | 13 | 60 |
| 120 | 132 | 123,5 | 10 | 17 | 11 | 52,8 | 41,5 | 227 | 87 | 17 | 68 |
| 140 | 164 | 148 | 16 | 24 | 12 | 90,8 | 71,3 | 459 | 176 | 21 | 76 |
| 160 | 182 | 167 | 16 | 25 | 14 | 106 | 83,5 | 611 | 233 | 23 | 86 |
| 180 | 202 | 187 | 16 | 25 | 14 | 120 | 93,8 | 785 | 292 | 25 | 100 |
| 200 | 220 | 206 | 16 | 26 | 15 | 136 | 107 | 991 | 369 | 25 | 110 |
| **I PE** | | | | | | | | | | | |
| 80 | 80 | 46 | 3,8 | 5,2 | 5 | 7,64 | 6,0 | 20,0 | 3,69 | 6,4 | 26 |
| 100 | 100 | 55 | 4,1 | 5,7 | 7 | 10,3 | 8,1 | 34,2 | 5,79 | 8,4 | 30 |
| 120 | 120 | 64 | 4,4 | 6,3 | 7 | 13,3 | 10,4 | 53,0 | 8,65 | 8,4 | 36 |
| 140 | 140 | 73 | 4,7 | 6,9 | 7 | 16,4 | 12,9 | 77,3 | 12,3 | 11 | 40 |
| 160 | 160 | 82 | 5,0 | 7,4 | 9 | 20,1 | 15,8 | 109 | 16,7 | 13 | 44 |
| 180 | 180 | 91 | 5,3 | 8,0 | 9 | 23,9 | 18,8 | 146 | 22,2 | 13 | 50 |

# Sheet metals

## Steel sheet

DIN 1541 (May 32) 1)
DIN 1542 (Apr. 59) 2)
DIN 1543 (Jul. 59) 3)

| Thickness of sheet in mm | sheet gauge No. | Weight ≈ kg/m² |
|---|---|---|
| 0,18 | 32 | 1,44 |
| 0,2 | 31 | 1,6 |
| 0,22 | 30 | 1,76 |
| 0,24 | 29 | 1,92 |
| 0,28 | 28 | 2,24 |
| 0,32 | 27 | 2,56 |
| 0,38 | 26 | 3,04 |
| 0,44 | 25 | 3,52 |
| 0,5 | 24 | 4 |
| 0,56 | 23 | 4,48 |
| 1) 0,63 | 22 | 5,04 |
| 0,75 | 21 | 6 |
| 0,88 | 20 | 7,04 |
| 1 | 19 | 8 |
| 1,13 | 18 | 9,04 |
| 1,25 | 17 | 10 |
| 1,38 | 16 | 11,04 |
| 1,5 | 15 | 12 |
| 1,75 | 14 | 14 |
| 2 | 13 | 16 |
| 2,25 | 12 | 18 |
| 2,5 | 11 | 20 |
| 2,75 | 10 | 22 |
| 3 | | 24 |
| 3,5 | | 28 |
| 2) 4 | | 32 |
| 4,5 | | 36 |
| 4,75 | | 38 |
| 5 | | 40 |
| 3) 6 | | 48 |
| 7 | | 56 |
| 8 | | 64 |

Material as per DIN 17100 (Sep. 66)

## Galvanized iron sheet

DIN 1540 (Apr. 70)

| Thickness of sheet in mm | Weight ≈ kg/m² |
|---|---|
| 0,15 | 1,27 |
| 0,19 | 1,54 |
| 0,22 | 1,76 |
| 0,24 | 1,92 |
| 0,27 | 2,16 |
| 0,28 | 2,24 |
| 0,31 | 2,48 |
| 0,32 | 2,56 |
| 0,36 | 2,88 |
| 0,37 | 2,96 |
| 0,41 | 3,28 |
| 0,43 | 3,39 |
| 0,46 | 3,63 |
| 0,50 | 3,90 |
| 0,52 | 4,11 |
| 0,57 | 4,50 |
| 0,58 | 4,58 |
| 0,64 | 4,99 |
| 0,66 | 5,15 |
| 0,70 | 5,46 |
| 0,75 | 5,85 |
| 0,80 | 6,24 |
| 0,90 | 7,02 |
| 1,00 | 7,8 |

Board sizes of galvanized iron sheet
265 x 380
380 x 530
530 x 760
435 x 650

Material as per DIN 1616 (May 67)

## Brass sheet DIN 1751 (Jun. 73)

| Thickness of sheet in mm | CuZn 40 Pb 3 Weight ≈ kg/m² | CuZn 33 Weight ≈ kg/m² |
|---|---|---|
| 0,10 | 0,85 | 0,86 |
| 0,15 | 1,28 | 1,30 |
| 0,20 | 1,70 | 1,73 |
| 0,25 | 2,13 | 2,16 |
| 0,30 | 2,55 | 2,6 |
| 0,35 | 2,98 | 3,03 |
| 0,40 | 3,40 | 3,46 |
| 0,45 | 3,83 | 3,89 |
| 0,50 | 4,25 | 4,32 |
| 0,55 | 4,68 | 4,76 |
| 0,60 | 5,10 | 5,19 |
| 0,65 | 5,53 | 5,62 |
| 0,70 | 5,95 | 6,06 |
| 0,75 | 6,38 | 6,49 |
| 0,80 | 6,80 | 6,92 |
| 0,85 | 7,23 | 7,35 |
| 0,90 | 7,65 | 7,79 |
| 1 | 8,50 | 8,65 |
| 1,10 | 9,35 | 9,52 |
| 1,20 | 10,20 | 10,38 |
| 1,30 | 11,1 | 11,25 |
| 1,40 | 11,9 | 12,11 |
| 1,50 | 12,8 | 12,98 |
| 1,6 | 13,6 | 13,84 |
| 1,70 | 14,5 | 14,71 |
| 1,80 | 15,3 | 15,57 |
| 2 | 17,0 | 17,30 |
| 2,50 | 21,3 | 21,63 |
| 2,80 | 23,8 | 24,22 |
| 3 | 25,5 | 25,95 |
| 3,20 | 27,2 | 27,68 |
| 3,50 | 29,8 | 30,26 |

Material as per DIN 17660 (Apr. 74)

## Copper sheet DIN 1751 (Jun. 73)

| Cu Weight ≈ kg/m² |
|---|
| 0,89 |
| 1,34 |
| 1,78 |
| 2,23 |
| 2,67 |
| 3,12 |
| 3,56 |
| 4,01 |
| 4,45 |
| 4,90 |
| 5,34 |
| 5,79 |
| 6,23 |
| 6,68 |
| 7,12 |
| 7,52 |
| 8,01 |
| 8,90 |
| 9,79 |
| 10,7 |
| 11,60 |
| 12,50 |
| 13,4 |
| 14,2 |
| 15,1 |
| 16,0 |
| 17,8 |
| 22,3 |
| 24,9 |
| 26,7 |
| 28,5 |
| 31,2 |

E-Cu OF-Cu DIN 1787 (Jan. 73)

## Aluminium sheet DIN 1783 (Oct. 63)

| Al Weight ≈ kg/m² |
|---|
| — |
| — |
| — |
| — |
| — |
| — |
| 1,08 |
| — |
| 1,35 |
| — |
| 1,62 |
| — |
| — |
| 2,16 |
| — |
| — |
| 2,70 |
| — |
| 3,24 |
| — |
| 4,05 |
| — |
| 4,86 |
| 5,40 |
| 6,75 |
| — |
| 8,10 |
| — |
| 9,45 |

Material: DIN 1745 (Dec. 68)

## Mg-alloy

| Mg Weight ≈ kg/m² |
|---|
| — |
| — |
| — |
| — |
| 0,546 |
| — |
| 0,728 |
| — |
| 0,910 |
| — |
| 1,09 |
| — |
| — |
| 1,46 |
| — |
| — |
| 1,82 |
| — |
| 2,18 |
| — |
| 2,73 |
| — |
| 3,28 |
| 3,64 |
| 4,55 |
| — |
| 5,46 |
| — |
| 6,37 |

Mg-Mn 2 Mg-Al 6 Zn DIN 1729 (Mai 63)

## Zinc-sheet DIN 9722 (Oct. 72)

| Zn Weight ≈ kg/m² |
|---|
| — |
| 1,08 |
| 1,44 |
| 1,80 |
| 2,15 |
| 2,51 |
| 2,87 |
| 3,23 |
| 3,59 |
| 3,95 |
| 4,31 |
| 4,67 |
| 5,03 |
| 5,38 |
| 5,74 |
| — |
| 6,46 |
| 7,18 |
| — |
| 8,62 |
| — |
| 10,1 |
| 10,8 |
| — |
| 12,9 |
| 14,4 |
| 18 |
| 20,1 |
| 21,5 |
| — |
| 25,1 |

Material DIN 1706 (Jul. 66)

Dimensions of steel sheets stocked

| Sheet-thickness | 0.18...0.44 | 0.18...0.28 | 0.28...0.38 | 0.32...0.38 | 0.44...2.75 | 0.5...2.75 | 1.5...2.75 |
|---|---|---|---|---|---|---|---|
| Stocked dimens. | 530 x 760 | 500 x 1000 | 600 x 1200 | 700 x 1400 | 800 x 1600 | 1000 x 2000 | 1250 x 2500 |

Nomenclature

| | |
|---|---|
| Black iron sheet II, 2.25 mm thick, 1000 mm wide, 2000 mm long made of RSt 42–2 | Black sheet II 2.25 x 1000 x 2000 DIN 1623 RSt. 42-2 |
| Brass sheets, 0.7 mm thick, 550 mm wide, 1900 mm long made of Cu Zn 30 | Sheet 0.7 x 550 x 1900 DIN 17660 Cu Zn 30 |
| Cu sheet, 6 mm thick, 1000 mm wide, 2000 mm long made of E-Cu F 20 | Copper sheet 0.6 x 1000 x 2000 fixed DIN 1752-E-CuF 20 gb |
| Aluminium sheet, 1.2 mm thick, 1000 mm wide, 2000 mm long: | Sheet 1.2 x 1000 x 2000 DIN 1783-AlCuMgF 38 |
| Manganese alloy sheets, 1.2 mm thick, 650 mm wide, 3000 mm long made of Mg-Mn | Sheet 1.2 x 650 x 3000 fixed DIN 9101 – Mg-Mn |
| Zinc sheet, 1.2 mm thick, 1000 mm wide, 2250 mm long in fixed sizes made of rolled zinc | Sheet 1.2 x 1000 x 2250 fixed DIN 9721 rolled zinc |

The word fixed comes after the sizes in fixed sizes. Details of width and length can be ommited in drawings and in lists of parts

Sheet 1.2 DIN 1783 Al Cu Mg F 38

# Non ferrous metal

## Round, square and hexagonal bars

| Diameter d side length s wrench size w d s w mm | Cu DIN 1756 (July 69) | Cu Zn DIN 1756 (July 69) | Al-alloy DIN 1798 (Feb. 68) | Mg-alloy | Cu Zn DIN 1761 (July 69) | Al-alloy DIN 1796 (Feb. 68) | Mg-alloy | Cu Zn DIN 1763 (July 69) | Al-alloy DIN 1797 (Feb. 68) | Mg-alloy |
|---|---|---|---|---|---|---|---|---|---|---|
| | kg/m ≈ | | | | kg/m ≈ | | | kg/m ≈ | | |
| 3 | 0,063 | 0,060 | 0,0191 | 0,0129 | 0,0765 | 0,0243 | — | 0,0662 | 0,0210 | — |
| 3,5 | 0,086 | 0,082 | 0,0260 | 0,0175 | 0,104 | 0,0331 | — | 0,0902 | 0,0286 | — |
| 4 | 0,112 | 0,107 | 0,0339 | 0,0229 | 0,136 | 0,0432 | 0,0291 | 0,118 | 0,0374 | 0,0252 |
| 4,5 | 0,142 | 0,135 | 0,0429 | 0,0289 | 0,172 | 0,0547 | 0,0369 | 0,149 | 0,0473 | 0,0319 |
| 5 | 0,175 | 0,167 | 0,0530 | 0,0357 | 0,212 | 0,0675 | 0,0455 | 0,184 | 0,0585 | 0,0394 |
| 5,5 | 0,211 | 0,202 | 0,0641 | 0,0432 | 0,257 | 0,0817 | 0,0551 | 0,223 | 0,0707 | 0,0477 |
| 6 | 0,252 | 0,240 | 0,0763 | 0,0515 | 0,306 | 0,0972 | 0,0655 | 0,265 | 0,0842 | 0,0567 |
| 7 | 0,343 | 0,327 | 0,104 | 0,0700 | 0,416 | 0,132 | 0,0892 | 0,361 | 0,115 | 0,0772 |
| 8 | 0,447 | 0,427 | 0,136 | 0,0915 | 0,544 | 0,173 | 0,116 | 0,471 | 0,150 | 0,101 |
| 9 | 0,566 | 0,541 | 0,172 | 0,116 | 0,688 | 0,219 | 0,147 | 0,596 | 0,189 | 0,128 |
| 10 | 0,699 | 0,668 | 0,212 | 0,143 | 0,850 | 0,270 | 0,182 | 0,736 | 0,234 | 0,158 |
| 11 | 0,846 | 0,808 | 0,257 | 0,173 | 1,03 | 0,327 | 0,220 | 0,891 | 0,283 | 0,191 |
| 12 | 1,007 | 0,961 | 0,305 | 0,206 | 1,22 | 0,389 | 0,262 | 1,06 | 0,337 | 0,227 |
| 14 | 1,370 | 1,31 | 0,416 | 0,280 | 1,67 | 0,529 | 0,357 | 1,44 | 0,458 | 0,309 |
| 20 | 2,796 | 2,67 | 0,848 | 0,572 | 3,40 | 1,08 | — | — | — | — |
| 22 | 3,383 | 3,23 | 1,03 | 0,692 | 4,11 | 1,31 | 0,881 | 3,56 | 1,13 | 0,763 |
| 24 | 4,028 | 3,85 | 1,22 | 0,823 | 4,90 | 1,56 | 1,05 | 4,24 | 1,35 | 0,908 |
| 32 | 7,158 | 6,84 | 2,17 | 1,46 | 8,70 | 2,76 | 1,86 | 7,54 | 2,39 | 1,61 |
| 36 | 9,059 | 8,65 | 2,75 | 1,85 | 11,0 | 3,50 | 2,36 | 9,54 | 3,03 | 2,04 |
| 50 | 17,475 | 16,7 | 5,30 | 3,57 | 21,2 | 6,75 | 4,55 | 18,4 | 5,85 | 3,94 |

| Symbols: | Round | Square | Hexagon |
|---|---|---|---|
| | 20 DIN 1756 SW-Cu F 20[1] | 22 DIN 1761 Cu Zn 20 F 33 | 22 DIN 1797 Al Mg Si F 11 |
| | 24 DIN 1782 Cu Zn 30 F 43 | 22 DIN 1796 Al Mg Si F... | 22 DIN 1763 Cu Zn 30 F 43 |
| | 22 DIN 1798 Al Mg Si F 11 | 22 DIN 9703 Mg-Mn F 11 | 22 DIN 9705 Mg-Mn F... |

## Flat bars (sharp-edged drawn)

| Nominal size a x b mm | Cu DIN 1768 (Oct. 63) | Cu Zn DIN 1759 (Oct. 63) | Al-alloy DIN 1770 (March 54) | Mg-alloy | Nominal size a x b mm | Cu DIN 1768 (Oct. 63) | Cu Zn DIN 1759 (Oct. 63) | Al-alloy DIN 1770 (March 54) | Mg-alloy |
|---|---|---|---|---|---|---|---|---|---|
| | kg/m ≈ | | | | | kg/m ≈ | | | |
| 5 · 2 | 0,089 | 0,085 | — | 0,0182 | 30 · 5 | 1,34 | 1,28 | 0,405 | 0,273 |
| 3 | 0,13 | 0,13 | — | 0,0273 | 8 | 2,14 | 2,04 | 0,648 | 0,437 |
| 4 | 0,18 | 0,17 | — | 0,0364 | 10 | 2,67 | 2,55 | 0,810 | 0,546 |
| 10 · 2 | 0,18 | 0,17 | 0,054 | 0,0364 | 40 · 5 | 1,78 | 1,70 | 0,540 | — |
| 3 | 0,27 | 0,26 | 0,081 | 0,0546 | 8 | 2,85 | 2,72 | — | — |
| 4 | 0,36 | 0,34 | 0,108 | 0,0728 | 10 | 3,56 | 3,40 | 1,08 | — |
| 5 | 0,45 | 0,43 | 0,135 | 0,0910 | 15 | 5,34 | 5,10 | 1,62 | 1,09 |
| 8 | 0,71 | 0,68 | 0,216 | 0,146 | 20 | 7,12 | 6,80 | 2,16 | 1,46 |
| 15 · 2 | 0,27 | 0,26 | 0,081 | 0,0546 | 50 · 5 | 2,23 | 2,13 | 0,675 | 0,455 |
| 3 | 0,40 | 0,38 | 0,122 | 0,0819 | 8 | 3,56 | 3,40 | 1,08 | 0,728 |
| 5 | 0,67 | 0,64 | 0,202 | 0,137 | 10 | 4,45 | 4,25 | 1,35 | 0,910 |
| 8 | 1,07 | 1,02 | 0,324 | 0,218 | 15 | 6,68 | 6,38 | 2,02 | 1,37 |
| 10 | 1,34 | 1,28 | 0,405 | 0,273 | 20 | 8,90 | 8,50 | 2,70 | 1,82 |
| 20 · 5 | 0,89 | 0,85 | 0,270 | 0,182 | 60 · 5 | 2,67 | — | 0,810 | — |
| 8 | 1,42 | 1,36 | 0,432 | 0,291 | 8 | 4,27 | — | 1,30 | — |
| 10 | 1,78 | 1,70 | 0,540 | 0,364 | 10 | 5,34 | 5,10 | 1,62 | — |
| 15 | 2,67 | 2,55 | 0,810 | 0,546 | 15 | 8,01 | — | 2,43 | — |

| Nomenclature: | | |
|---|---|---|
| | Flat 10 x 4 DIN 1768 E-Cu 58 | Flat 10 x 4 DIN 1759 Cu Zn 5 |
| | Flat or Fl 10 x 4 DIN 1770-Al Mg Si F 13 | Flat 10 x 4 DIN 9701-Mg-Mn F... |

1) Hardness and surface finish as per DIN 1750

Material: Cu as per DIN 1787, Cu Zn as per DIN 17660. Al-alloy as per DIN 1725. Mg-alloy as per DIN 1729. Pg. 1

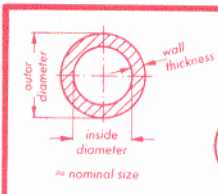
# Light metal

Weight of Al and Al-alloy with $\varrho = 2.7$ kg/dm³ calculated
Weight of Mg-alloy with $\varrho = 1.8$ kg/dm³ calculated
for $\varrho = 2.6$ kg/dm³ multiply the values by 0.963
for $\varrho = 2.8$ kg/dm³ multiply the values by 1.037

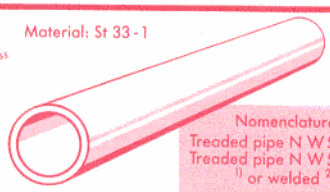
Material:
Aluminium as per DIN 1712 (Oct. 61)
Al-alloys as per DIN 1725 (Feb. 67)
Mg-alloys as per DIn 1729 (May 63)
Supplied as bars with minimum length of 2 m

Nomenclature
E.g. T 35·35·2.5 DIN 9714 AlMg2F18
L 30·15·2 DIN 1771 AlMg2F18
I 60·50·3 DIN 9712 AlMg2F18
C 50·40·4 DIN 9713 AlMg2F18

| | Dimensions height, width, thickness | Cross Section | Weight in kg/m | | Distance of the centroidal axis | | Section modulus | |
|---|---|---|---|---|---|---|---|---|
| | | | $\varrho = 2{,}7$ | $\varrho = 1{,}8$ | $x-x$ | $y-y$ | $x-x$ | $y-y$ |
| | $h \times b \times s$ (xt) | T | | | $e_x$ | $e_y$ | $W_x$ | $W_y$ |
| | mm | cm² | kg/m | kg/m | cm | cm | cm³ | cm³ |
| **T-Profile,** pressed DIN 9714 (Aug. 69) | 20x30x2 | 0,969 | 0,262 | 0,174 | 0,475 | 1,50 | 0,681 | 0,308 |
| | 2,5 | 1,21 | 0,327 | 0,218 | 0,494 | 1,50 | 0,781 | 0,375 |
| | 3 | 1,44 | 0,389 | 0,259 | 0,512 | 1,50 | 0,881 | 0,452 |
| | 25x40x2 | 1,27 | 0,343 | 0,229 | 0,557 | 2,00 | 1,18 | 0,504 |
| | 2,5 | 1,59 | 0,429 | 0,286 | 0,574 | 2,00 | 1,42 | 0,665 |
| | 3 | 1,89 | 0,510 | 0,340 | 0,594 | 2,00 | 1,57 | 0,800 |
| | 30x30x2 | 1,17 | 0,316 | 0,211 | 0,824 | 1,50 | 1,25 | 0,300 |
| | 2,5 | 1,46 | 0,394 | 0,263 | 0,830 | 1,50 | 1,48 | 0,376 |
| | 3 | 1,74 | 0,470 | 0,313 | 0,861 | 1,50 | 1,67 | 0,452 |
| | 30x45x2,5 | 1,84 | 0,497 | 0,331 | 0,694 | 2,25 | 1,98 | 0,844 |
| | 3 | 2,19 | 0,591 | 0,394 | 0,713 | 2,25 | 2,24 | 1,01 |
| | 4 | 2,87 | 0,775 | 0,517 | 0,750 | 2,25 | 2,78 | 1,35 |
| | 35x35x2,5 | 1,71 | 0,462 | 0,308 | 0,968 | 1,75 | 2,05 | 0,502 |
| | 3 | 2,04 | 0,551 | 0,367 | 0,986 | 1,75 | 2,37 | 0,617 |
| | 4 | 2,67 | 0,721 | 0,481 | 1,02 | 1,75 | 2,94 | 0,841 |
| | 35x50x3 | 2,49 | 0,672 | 0,448 | 0,833 | 2,50 | 3,12 | 1,26 |
| | 4 | 3,27 | 0,883 | 0,589 | 0,870 | 2,50 | 3,85 | 1,67 |
| | 5 | 4,07 | 1,10 | 0,733 | 0,906 | 2,50 | 4,42 | 2,09 |
| **L-Profile,** pressed DIN 1771 (Aug. 69) | 10x10x1,5 | 0,282 | 0,076 | 0,051 | 0,305 | 0,305 | 0,079 | 0,079 |
| | 2 | 0,364 | 0,098 | 0,066 | 0,322 | 0,322 | 0,096 | 0,096 |
| | 2,5 | 0,450 | 0,122 | 0,081 | 0,339 | 0,339 | 0,105 | 0,105 |
| | 10x20x1,5 | 0,432 | 0,117 | 0,078 | 0,224 | 0,724 | 0,134 | 0,242 |
| | 2 | 0,564 | 0,152 | 0,102 | 0,243 | 0,743 | 0,155 | 0,299 |
| | 2,5 | 0,700 | 0,189 | 0,126 | 0,261 | 0,761 | 0,167 | 0,348 |
| | 15x15x1,5 | 0,432 | 0,117 | 0,078 | 0,430 | 0,430 | 0,208 | 0,209 |
| | 2 | 0,564 | 0,152 | 0,102 | 0,448 | 0,448 | 0,254 | 0,254 |
| | 2,5 | 0,700 | 0,189 | 0,126 | 0,446 | 0,446 | 0,286 | 0,286 |
| | 15x20x1,5 | 0,507 | 0,137 | 0,091 | 0,377 | 0,627 | 0,260 | 0,322 |
| | 2 | 0,664 | 0,179 | 0,120 | 0,396 | 0,646 | 0,316 | 0,402 |
| | 2,5 | 0,825 | 0,223 | 0,148 | 0,414 | 0,664 | 0,360 | 0,464 |
| | 15x30x2 | 0,864 | 0,233 | 0,156 | 0,327 | 1,08 | 0,428 | 0,729 |
| | 2,5 | 1,06 | 0,286 | 0,191 | 0,346 | 1,10 | 0,483 | 0,861 |
| | 3 | 1,26 | 0,340 | 0,227 | 0,364 | 1,11 | 0,530 | 1,04 |
| **I-Profile,** pressed DIN 9712 (Aug. 69) | 40x40x3x3 | 3,47 | 0,937 | 0,625 | 2,00 | 2,00 | 4,69 | 1,60 |
| | 4x4 | 4,53 | 1,22 | 0,815 | 2,00 | 2,00 | 5,80 | 2,14 |
| | 45x45x3x3 | 3,92 | 1,06 | 0,705 | 2,25 | 2,25 | 6,04 | 2,02 |
| | 4x4 | 5,13 | 1,39 | 0,923 | 2,25 | 2,25 | 7,59 | 2,70 |
| | 4x5 | 6,38 | 1,73 | 1,15 | 2,25 | 2,25 | 9,02 | 3,38 |
| | 50x50x3x3 | 4,37 | 1,18 | 0,787 | 2,50 | 2,50 | 7,64 | 2,50 |
| | 4x4 | 5,73 | 1,55 | 1,03 | 2,50 | 2,50 | 9,59 | 3,34 |
| | 50x50x4x6 | 7,66 | 2,01 | 1,38 | 2,50 | 2,50 | 12,7 | 5,00 |
| | 60x50x3x3 | 4,67 | 1,26 | 0,841 | 3,00 | 2,50 | 9,57 | 2,51 |
| | 4x4 | 6,13 | 1,66 | 1,10 | 3,00 | 2,50 | 12,2 | 3,34 |
| | 60x60x4x6 | 6,93 | 1,87 | 1,25 | 3,00 | 3,00 | 14,2 | 4,80 |
| | 60x60x4x6 | 9,26 | 2,50 | 1,67 | 3,00 | 3,00 | 19,1 | 7,20 |
| **C-Profile,** pressed DIN 9713 (Aug. 69) | 40x20x2 | 1,53 | 0,413 | 0,275 | 2,0 | 0,574 | 1,85 | 0,995 |
| | 3 | 2,25 | 0,608 | 0,405 | 2,0 | 0,610 | 2,59 | 1,30 |
| | 40x30x3 | 2,85 | 0,770 | 0,513 | 2,0 | 1,01 | 3,62 | 2,49 |
| | 4 | 3,71 | 1,00 | 0,668 | 2,0 | 1,05 | 4,49 | 3,03 |
| | 40x40x4 | 4,51 | 1,22 | 0,812 | 2,0 | 1,49 | 5,80 | 4,80 |
| | 5 | 5,57 | 1,50 | 1,00 | 2,0 | 1,52 | 6,80 | 5,64 |
| | 50x30x3 | 3,15 | 0,850 | 0,567 | 2,5 | 0,929 | 4,88 | 2,91 |
| | 4 | 4,11 | 1,11 | 0,740 | 2,5 | 0,965 | 6,20 | 3,80 |
| | 50x40x4 | 4,91 | 1,33 | 0,884 | 2,5 | 1,38 | 7,83 | 5,65 |
| | 5 | 6,07 | 1,64 | 1,09 | 2,5 | 1,42 | 9,32 | 6,54 |
| | 60x30x4 | 4,51 | 1,22 | 0,812 | 3,0 | 0,896 | 7,90 | 4,12 |
| | 5 | 5,57 | 1,50 | 1,00 | 3,0 | 0,932 | 9,47 | 4,70 |




Material: St 33 - 1



Nomenclature:
Treaded pipe N W 50 DIN 2440 seamless[1] black[2]
Treaded pipe N W 50 DIN 2441 seamless[1] black[2]
[1] or welded [2] or galvanized

| Medium heavy threaded pipes DIN 2440 (July 72) | | | | | Heavy threaded pipes DIN 2441 (July 72) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nominal diameter in | | Outer ∅ ≈ | Wall thickness ≈ | Weight | Nominal diameter in | | Outer ∅ ≈ | Wall thickness ≈ | Weight | Pipe nominal diameter | Thread thread ∅ theoret. | Thread no. of threads |
| inch | mm | mm | mm | kg/m | inch | mm | mm | mm | kg/m | inch | mm | per inch |
| 1/8 | 6 | 10,2 | 2,0 | 0,407 | 1/8 | 6 | 10,2 | 2,65 | 0,493 | 1/8 | 9,728 | 28 |
| 1/4 | 8 | 13,5 | 2,35 | 0,650 | 1/4 | 8 | 13,5 | 2,9 | 0,769 | 1/4 | 13,157 | 19 |
| 3/8 | 10 | 17,2 | 2,35 | 0,852 | 3/8 | 10 | 17,2 | 2,9 | 1,02 | 3/8 | 16,662 | 19 |
| 1/2 | 15 | 21,3 | 2,65 | 1,22 | 1/2 | 15 | 21,3 | 3,25 | 1,45 | 1/2 | 20,955 | 14 |
| 3/4 | 20 | 26,9 | 2,65 | 1,58 | 3/4 | 20 | 26,9 | 3,25 | 1,90 | 3/4 | 26,442 | 14 |
| 1 | 25 | 33,7 | 3,25 | 2,44 | 1 | 25 | 33,7 | 4,05 | 2,97 | 1 | 33,249 | 11 |
| 1 1/4 | 32 | 42,4 | 3,25 | 3,14 | 1 1/4 | 32 | 42,4 | 4,05 | 3,84 | 1 1/4 | 41,910 | 11 |
| 1 1/2 | 40 | 48,3 | 3,25 | 3,61 | 1 1/2 | 40 | 48,3 | 4,05 | 4,43 | 1 1/2 | 47,803 | 11 |
| 2 | 50 | 60,3 | 3,65 | 5,10 | 2 | 50 | 60,3 | 4,5 | 6,17 | 2 | 59,614 | 11 |
| 2 1/2 | 65 | 76,1 | 3,65 | 6,51 | 2 1/2 | 65 | 76,1 | 4,5 | 7,90 | 2 1/2 | 75,184 | 11 |
| 3 | 80 | 88,9 | 4,05 | 8,47 | 3 | 80 | 88,9 | 4,85 | 10,1 | 3 | 87,884 | 11 |
| 4 | 100 | 114,3 | 4,5 | 12,1 | 4 | 100 | 114,3 | 5,4 | 14,4 | 4 | 113,030 | 11 |
| 5 | 125 | 139,7 | 4,85 | 16,2 | 5 | 125 | 139,7 | 5,4 | 17,8 | 5 | 138,430 | 11 |
| 6 | 150 | 165,1 | 4,85 | 19,2 | 6 | 150 | 165,1 | 5,4 | 21,2 | 6 | 163,830 | 11 |

Aluminium pipes DIN 1746 (Dec. 68) $\varrho = 2.7$ kg/dm$^3$
Brass pipes DIN E 1755 (Dec. 71) $\varrho = 8.5$ kg/dm$^3$
Copper pipes DIN 59750 (June 74) $\varrho = 8.9$ kg/dm$^3$

Nomenclature:
Pipes 30 x 1 DIN 1746 Al 99 F 11
Brass pip. 25 x 1.5 DIN 1755 Cu Zn 30 hbk
Copper pipes 20 x 24 DIN 59750 w bk
(h = hard, -w = soft, bk = normal)

| Outer ∅ | Weight in kg/m Wall thickness 0,5 mm | | | 0,8 | 0,75 mm | | 1 mm | | | 1,5 mm | | | 2 mm | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| mm | Al | Ms | Cu | Al | Ms | Cu | Al | Ms | Cu | Al | Ms | Cu | Al | Ms | Cu |
| 3 | 0,011 | | | 0,015 | | | | | | | | | | | |
| 4 | 0,015 | | | 0,022 | | | | | | | | | | | |
| 5 | 0,019 | 0,06 | | 0,029 | 0,08 | | | 0,11 | 0,11 | | 0,14 | | | | |
| 6 | 0,023 | 0,07 | 0,077 | 0,035 | 0,10 | 0,11 | 0,042 | 0,13 | 0,14 | | 0,18 | | | | |
| 7 | 0,028 | 0,09 | 0,09 | 0,042 | 0,13 | 0,13 | 0,051 | 0,16 | 0,17 | | 0,22 | 0,23 | | | 0,28 |
| 8 | 0,032 | 0,10 | 0,104 | 0,049 | 0,15 | 0,15 | 0,059 | 0,19 | 0,20 | 0,083 | 0,26 | 0,28 | | | 0,34 |
| 10 | 0,040 | 0,13 | 0,13 | 0,063 | 0,19 | 0,20 | 0,076 | 0,24 | 0,25 | 0,108 | 0,34 | 0,36 | 0,136 | | 0,45 |
| 12 | 0,049 | 0,14 | | 0,076 | 0,23 | | 0,093 | 0,29 | 0,31 | 0,134 | 0,42 | 0,44 | 0,170 | 0,53 | 0,56 |
| 13 | 0,053 | | | 0,083 | | | 0,102 | 0,32 | 0,34 | 0,146 | 0,46 | 0,48 | 0,187 | 0,59 | 0,62 |
| 14 | 0,057 | | | 0,092 | | | 0,110 | | 0,36 | 0,159 | | 0,53 | 0,204 | | 0,67 |
| 15 | 0,062 | | | 0,096 | | | 0,119 | 0,37 | 0,39 | 0,172 | 0,54 | 0,57 | 0,221 | 0,69 | 0,73 |
| 16 | 0,066 | | | 0,103 | | 0,32 | 0,127 | 0,40 | 0,42 | 0,184 | 0,58 | 0,61 | 0,238 | | 0,79 |
| 18 | 0,074 | | 0,26 | 0,115 | | | 0,144 | 0,45 | 0,48 | 0,210 | 0,66 | 0,70 | 0,271 | 0,85 | 0,90 |
| 19 | 0,079 | | | 0,123 | | | 0,153 | 0,48 | | 0,223 | 0,70 | 0,74 | 0,288 | | 0,95 |
| 20 | 0,083 | | | 0,130 | | | 0,161 | 0,51 | 0,53 | 0,235 | 0,74 | 0,78 | 0,305 | 0,96 | 1,01 |
| 22 | 0,091 | | | 0,146 | | | 0,178 | 0,56 | 0,59 | 0,261 | 0,82 | 0,86 | 0,339 | 1,07 | 1,12 |
| 25 | 0,104 | | | 0,164 | | | 0,204 | 0,64 | 0,67 | 0,299 | 0,94 | 0,98 | 0,390 | 1,23 | 1,29 |
| 28 | 0,117 | | | 0,183 | | | 0,229 | 0,72 | 0,76 | 0,337 | 1,06 | 1,12 | 0,441 | 1,39 | 1,47 |
| 30 | 0,125 | | | 0,199 | | | 0,246 | 0,77 | 0,82 | 0,363 | 1,14 | 1,20 | 0,475 | 1,50 | 1,57 |
| 32 | | | | 0,214 | | | 0,263 | 0,83 | 0,87 | 0,388 | 1,22 | 1,28 | 0,509 | 1,60 | 1,68 |
| 36 | | | | 0,238 | | | 0,297 | | 0,98 | 0,439 | | 1,45 | 0,577 | | 1,91 |

## Abbreviations of nomenclatures for semi-finished products

DIN 1353 (April 71)

| | Nomenclature [1] | Meaning |
|---|---|---|
| ⌀ | 20x100 DIN 668 | Round steel, normal, 20 mm diameter, 100 mm total length as per DIN 668 |
| □ | 10x160 DIN 1761 | Square brass, drawn, 10 mm thick, 160 mm total length as per DIN 1761 |
| ▭ | 70x2x525 DIN 1016 | Steel strips, 70 mm breadth, 2 mm thick, 525 mm total length as per DIN 1016 |
| ▭ | 40x12x186 DIN 1017 | Flat steel, 40 mm breadth, 12 mm thick, 186 mm total length as per DIN 1017 |
| ▭ | 1.2x500x615 DIN 1784 | Strip of Al-wrought alloy, 1,2 mm thick, 500 mm breadth, 615 mm long as per DIN 1784 |
| ▭ | 0,5x8x430 DIN 1791 | Brass strips, 0,5 mm thick, 8 mm breadth, 430 mm total length as per DIN 1791 |
| ⬡ | 22x210 DIN 1797 | Hexagon bars of Al-wrought alloy, 22 mm wrench size, 210 mm total length |
| ⌓ | 25x8x380 DIN 1018 | Flat half round steel, 25 mm breadth, 8 mm high, 380 mm length as per DIN 1018 |
| L | 80x10x60Lg DIN 1028 | Angle steel with equal sides, 80 mm leg length, 10 mm leg thickness, 60 mm total length as per DIN 1028 |
| L | 100x50x10x805 DIN 1029 | Angle steel, unequal sides, 100 mm and 50 mm leg length, 10 mm leg thickness, 805 mm total length as per DIN 1029 |
| L | 40x25x4x430 DIN 1771 | Angle of Al or Al-wrought alloy or Mg-wrought alloy, unequal sides, leg length, 40 mm and 25 mm, 4 mm thickness, 40 mm length DIN 1771 |
| Z | 120x475 DIN 1027 | Z-steel, 120 mm high, 475 mm total length, as per DIN 1027 |
| T | 80x658 DIN 1024 | T-steel, deep legged of 80 mm height, 658 mm total length DIN 1024 |
| TB | 50x215 DIN 1024 | T-steel, broad-flanged of 50 mm height, 215 mm total length DIN 1024 |
| TPS | 30x420 DIN 59051 | T-steel, parallel flange and adjacent sides, sharp edged of 30 mm height 420 mm, total length acc. to DIN 59051 |
| I | 360x836 DIN 1025 | Double T-steel, narrow T-beam with inclined flange surface of 360 mm height, 836 total length, as per DIN 1025 (Pg. 1) |
| IB | 360x1264 DIN 1025 | Double T-steel, broad flange beams with inclined flange surface of 360 mm height, 1264 mm total length as per DIN 1025 (Pg 2) |
| IPB | 360x1175 DIN 1025 | Double T-steel, broad flange beams with parallel flange surfaces of 360 mm height, 1175 mm total length as per DIN 1025 (Pg 2) |
| IPBl | 360x1028x DIN 1025 | Double T-steel, broad flange beams, parallel flange surfaces, light-weight type of 360 mm height, 1028 mm length as per DIN 1025 (Pg 3) |
| IPBv | 360x1590 DIN 1025 | Double T-steel, broad-flanged, parallel flange surfaces, heavy duty type of 360 mm height, 1590 mm total length as per DIN 1025 (Pg 4) |
| IPE | 360x925 DIN 1025 | T-steel, medium breadth with parallel flange surfaces of 360 mm height, 925 mm total length as per DIN 1025 (Pg 5) |
| ⟶ | B80x5,5x680 DIN 1017 | Flat bulb steel with double sided collar (B), 80 mm breadth, 5,5 mm thick, 680 mm length |
| ⌙ | 150x75x8x860 DIN 1020 | Angled bulb steel, 150 mm and 75 mm flange breadth, 8 mm thick, 860 mm length |
| ⊥ | 24x3000 DIN 5902 | Railing of 24.43 kg/m, mass being referred to unit length. 3000 mm total length |
| Dr | 5x118 DIN 177 | Steel wires, drawn, 5 mm diameter, 118 mm total length as per DIN 177 |
| Ro | 80x6x346 DIN 2442 | Seamless threaded-steel pipes, without threads, 80 mm nominal diameter, 6 mm wall thickness, 346 mm total length as per DIN 2442 |
| Ro | 133x4x525 DIN 2448 | Seamless steel pipe, 133 mm outer diameter, 4 mm wall thickness, 525 mm length |
| PL | 3x75x185 DIN 7712 | Plates made of hard rubber, 3 mm thickness, 75 mm breadth, 185 mm length DIN 7712 |
| Tfl | 0,6x80x160 DIN 40605 | Board made of laminated paper, 0,6 mm nominal diameter, 80 mm breadth 160 mm length DIN 40605 |

[1] In graphic presentations the DIN numbers can be omitted, as there would be no confusion The symbols are supplemented by the material specifications if necessary, e.g. 20x100 DIN 668 St 37 k.
For clarification, the letter „Lg" can be added after the length measurements. „Lg" must however only be added if the length specifications are not definable by its size as length, e.g. 180x10x60Lg. (Finish length 60 mm)

# NUMBERS

## Calculation rules

| Common fractions | Decimal fractions |
|---|---|

### Addition and subtraction

**Common fractions**

First convert to get a common denominator

$$\frac{1}{2}+\frac{2}{3}=\frac{3}{6}+\frac{4}{6}=\frac{3+4}{6}=\frac{7}{6}=1\frac{1}{6}$$

$$\frac{3}{4}-\frac{2}{3}=\frac{9}{12}-\frac{8}{12}=\frac{9-8}{12}=\frac{1}{12}$$

**Decimal fractions**

Treat as whole numbers but bring the decimal points exactly under decimal point

| | |
|---|---|
| 14.370 | 14.370 |
| + 2.035 | −2.035 |
| 16.405 | 12.335 |

### Multiplication

**Common fractions**

Numerator × numerator
Denominator × denominator

$$\frac{2}{3}\times\frac{3}{4}=\frac{2\times3}{3\times4}=\frac{6}{12}=\frac{1}{2}=0{,}5$$

**Decimal fractions**

Treat them as whole numbers. Shift the decimal point to as many places in the product as one counts total decimal places in both factors.

1.4 × 0.02 (1 + 2 decimal places)

14 × 2 = 28
0,028

### Division

**Common fractions**

Multiplication with reciprocal of the second fraction

$$\frac{3}{4}:\frac{2}{3}=\frac{3}{4}\times\frac{3}{2}=\frac{3\times3}{4\times2}=\frac{9}{8}=1\frac{1}{8}$$

**Decimal fractions**

Shift the decimal point in both numbers as far right as possible to obtain whole number

1.5 : 0.25 = 150 : 25 = 6

Decimal moves 2 places

### % Calculation of percentage

$\left(1\,\% = \frac{1}{100}\right)$

| | |
|---|---|
| Percent value = $\frac{\text{Basic value} \times \text{Percentage}}{100}$ | Basic value: 750 DM, Percentage 4 ½ %<br>Percent value = $\frac{750 \times 4{,}5}{100} = 33{,}75$ DM |
| Basic value = $\frac{\text{Percent value} \times 100}{\text{Percentage}}$ | Percent value: 1920 DM, Percentage 6 %<br>Basic value = $\frac{1920 \times 100}{6} = 32.000$ DM |
| Percentage = $\frac{\text{Percent value} \times 100}{\text{Basic value}}$ | Percent value: 240 DM, Basic value 7200 DM<br>Percentage = $\frac{240 \times 100}{7200} = 3\frac{1}{2}\,\%$ |

### % Interest calculation

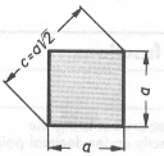
| | Examples: |
|---|---|
| Interest = $\frac{\text{Principal} \times \text{rate of interest} \times \text{time}}{100}$ | Principal: 5500<br>Rate of interest: 3 %<br>Time: 2 ½ years<br>Interest = $\frac{5500 \times 3 \times 5}{100 \times 2} = 412{,}50$ DM |
| Principal = $\frac{\text{Interest} \times 100}{\text{Time} \times \text{rate of interest}}$ | Rate of interest: 4 %<br>Time: 72 days<br>Interest: 22.40 DM<br>Principal = $\frac{22.40 \times 360 \times 100}{72 \times 4} = 2800$ DM |
| Rate of interest = $\frac{\text{Interest} \times 100}{\text{Principal} \times \text{time}}$ | Principal: 2400<br>Interest: 30 DM<br>Time: 3 months<br>Rate of Interest = $\frac{30 \times 100 \times 12}{2400 \times 3} = 5\,\%$ |
| Time = $\frac{\text{Interest} \times 100}{\text{Principal} \times \text{rate of interest}}$ | Principal: 2500<br>Interest: 300 DM<br>Rate of interest: 4 %<br>Time = $\frac{300 \times 100}{2500 \times 4} = 3$ years |

Time: 1 year = 360 days, 1 month = 30 days

# Calculation of areas

## Square

Area = Side × Side



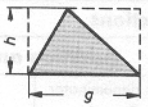

$$A = a \cdot a$$

$$A = a^2$$

$$a = \sqrt{A}$$

## Triangle

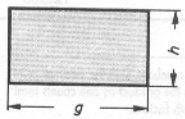
Area = $\frac{\text{Base} \times \text{Height}}{2}$




$$A = \frac{g \cdot h}{2} \qquad g = \frac{2A}{h} \qquad h = \frac{2A}{g}$$

## Rectangle

Area = Base × Height



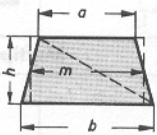

$$A = g \cdot h$$

$$g = \frac{A}{h}$$

$$h = \frac{A}{g}$$

## Trapezium

Area = Average sidelength × Height



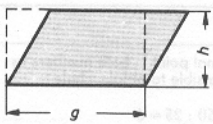

$$A = m \cdot h$$

$$A = \frac{a+b}{2} \cdot h \qquad h = \frac{2A}{a+b}$$

$$a = \frac{2A}{h} - b \; ; \; b = \frac{2A}{h} - a$$

## Parallelogram

Area = Length × Height




$$A = g \cdot h$$

$$g = \frac{A}{h}$$

$$h = \frac{A}{g}$$

## Regular polygon

Area = Area of one triangle × No. of sides $n$

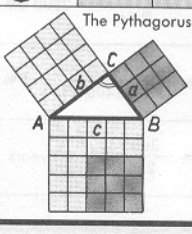
$$A = \frac{g \cdot h}{2} \cdot n$$

$$s = g$$

The following table enables one to compute for regular polygons:
Area **A**, if $s$ or R or $r$ are known; side **S**, if **R** or $r$ are known;
circumscribed circle radius **R** if $s$ or $r$ are known; inscribed circle radius **r**, if $s$ or $R$ are known

| n-sides or n-corner | Area $A$ = | | | Side $s$ = | | Radius of circum = scribed circle $R$ = | | Radius of inscribed circle $r$ = | |
|---|---|---|---|---|---|---|---|---|---|
| | $s^2$ times | or $R^2$ times | or $r^2$ times | $R$ times | or $r$ times | $s$ times | or $r$ times | $R$ times | or $s$ times |
| 3 sides | 0.4330 | 2.990 | 5.1962 | 1.7321 | 3.4641 | 0.5774 | 2.0000 | 0.5000 | 0.2887 |
| 4 sides | 1.0000 | 2.0000 | 4.0000 | 1.4142 | 2.0000 | 0.7071 | 1.4142 | 0.7071 | 0.5000 |
| 5 sides | 1.7205 | 2.3776 | 3.6327 | 1.1756 | 1.4531 | 0.8507 | 1.2361 | 0.8090 | 0.6882 |
| 6 sides | 2.5981 | 2.5981 | 3.4641 | 1.0000 | 1.1547 | 1.0000 | 1.1547 | 0.8660 | 0.8660 |
| 8 sides | 4.8284 | 2.8284 | 3.3137 | 0.7654 | 0.8284 | 1.3066 | 1.0824 | 0.9239 | 1.2071 |
| 10 sides | 7.6942 | 2.9389 | 3.2492 | 0.6180 | 0.6498 | 1.6180 | 1.0515 | 0.9511 | 1.5388 |
| 12 sides | 11.1960 | 3.0000 | 3.2154 | 0.5176 | 0.5359 | 1.9319 | 1.0353 | 0.9659 | 1.8660 |

### The Pythagorus theorem




The square of the hypotenuse is equal to the sum of the squares of the other two sides (Cathetus)
$c$ = hypotenuse, is opposite to the rigth angle
$a$, $b$ = cathetus, two sides forming the right angle

$$c^2 = a^2 + b^2$$

$$c = \sqrt{a^2 + b^2} \qquad a = \sqrt{c^2 - b^2} \qquad b = \sqrt{c^2 - a^2}$$

Example: $a = 6; \quad b = 8; \quad c = ?$

$$c = \sqrt{a^2 + b^2} = \sqrt{36 + 64} = \sqrt{100} = 10$$

Divide into sub-areas

$A$ = sum of sub-areas

$A = A_1 + A_2 + A_3$

$$A = \frac{g_1 \cdot h_1 + g_2 \cdot h_2 + g_2 \cdot h_3}{2}$$

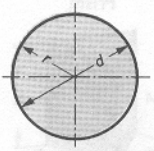
Irregular polygon

$A = \frac{\pi}{4} \cdot$ diameter $\cdot$ diameter

$U = \pi \cdot d$

$A = \pi \cdot r^2$ or $A = \left(\frac{\pi}{4} \cdot d^2\right) = 0{,}785 \cdot d^2$

Circle




$A$ = Bigger circle area – smaller circle area

$A = \left(\frac{\pi}{4} D^2\right) - \left(\frac{\pi}{4} d^2\right)$ $A = \frac{\pi}{4}(D^2 - d^2)$ $A = 0{,}785 \cdot (D^2 - d^2)$

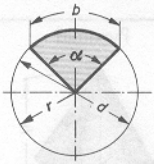
Circular ring

$A =$ arc length $\cdot$ radius $/ 2$

$A = \frac{\pi \cdot r^2 \cdot \alpha}{360}$

$A = \frac{\pi}{4} \frac{d^2 \cdot \alpha}{360}$ $b = \frac{\pi \cdot d \cdot \alpha}{360}$ $A = \left(\frac{b \cdot r}{2}\right)$

Sector of a circle



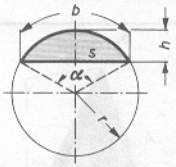

$A$ = Sector of a circle – Area of triangle

$$A = \left(\frac{\pi \cdot r^2 \cdot \alpha}{360}\right) - \left(\frac{s(r-h)}{2}\right)$$

$b = \frac{\pi \cdot d \cdot \alpha}{360}$ $s = 2 \cdot r \cdot \sin\frac{\alpha}{2}$

Approximately: $A = \frac{2}{3} \cdot s \cdot h$ $h = \frac{s}{2} \cdot \tan\frac{\alpha}{4}$

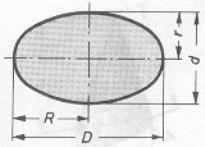
Segment of a circle




$A = \frac{\pi}{4} \cdot$ major axis $\cdot$ minor axis

$A = \frac{\pi}{4} \cdot D \cdot d$ $A = 0{,}785 \cdot D \cdot d$ $A = \pi \cdot R \cdot r$

Ellipse



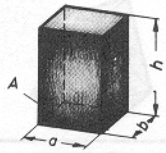

| $U$ depends on the ratio $d : D$ | | | |
|---|---|---|---|
| For $d : D$ | $U = D$ times | $d : D$ | $U = D$ times |
| 0,9 | 2,9866 | 0,5 | 2,4221 |
| 0,8 | 2,8361 | 0,4 | 2,3013 |
| 0,7 | 2,6912 | 0,3 | 2,1930 |
| 0,6 | 2,5527 | 0,2 | 2,1010 |

Example:

$D = 150$ mm
$d = 90$ mm
$d : D = 90 : 150 = 0{,}6$
$U = 150 \cdot 2{,}5527$
$U = 382{,}9$ mm

# Calculation of solids

## Prism




(Volume) = base area · height.

$V = A \cdot h$

$V = A_{\square} \cdot h$

$V = A_{\square} \cdot h$

$V = a \cdot b \cdot h$

Outer surface area

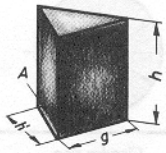
$A_O = 2A_{\square} + 4A_{\square}$

$A$ = square

$A_O = 2A_{\square} + 2A_{\square 1} + 2A_{\square 2}$

$A$ = rectangle

## Prism




$V = A \cdot h$

$V = A_{\triangle} \cdot h$

$V = \frac{g \cdot h'}{2} \cdot h$

$A_O = 2A_{\triangle} + 3A_{\square 1}$

$A$ = equilateral triangle

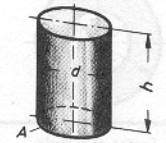
$A_O = 2A_{\triangle} + A_{\square 1} + A_{\square 2} + A_{\square 3}$

$A$ = oblique triangle

$A_O = 2A_{\triangle} + n \cdot A_{\square}$

$A$ = regular polygon of n-sides

## Cylinder




$V = A \cdot h$

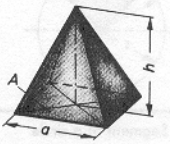
$V = A_O \cdot h$

$V = \frac{\pi}{4} \cdot d^2 \cdot h$

Outer surface area

$A_M = \pi \cdot d \cdot h$

## Pyramid




Volume = $\frac{\text{base surface area} \cdot \text{height}}{3}$

$V = \frac{A \cdot h}{3}$

$V = \frac{A_{\square} \cdot h}{3}$

$V = \frac{a \cdot b \cdot h}{3}$

Surface

$A_O = A_{\square} + 4A_{\triangle 1}$

$A$ = square base

$A_O = A_{\square} + 2A_{\triangle 1} + 2A_{\triangle 2}$

$A$ = rectangle

## Pyramid

$V = \frac{A \cdot h}{3}$

$V = \frac{A_{\triangle} \cdot h}{3}$

$V = \frac{g \cdot h' \cdot h}{2 \cdot 3}$

$A_O = A_{\triangle} + 3A_{\triangle 1}$

$A$ = equilateral triangle

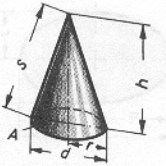
$A_O = A_{\triangle} + A_{\triangle 1} + A_{\triangle 2} + A_{\triangle 3}$

$A$ = oblique triangle

$A_O = A_{\triangle} + n \cdot A_{\triangle 1}$

$A$ = regular polygon of n-sides

## Cone




$V = \frac{A \cdot h}{3}$

$V = \frac{A_{\bigcirc} \cdot h}{3}$

$V = \frac{\pi}{4} \cdot d^2 \cdot \frac{h}{3}$

$A_O = \frac{\pi}{4} \cdot d(d + 2s)$

Outer surface area

$A_M = \frac{\pi \cdot d \cdot s}{2}$

$A_M = \pi \cdot r \sqrt{r^2 + h^2}$

## Surface area

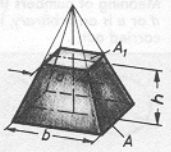
$A_O$ = sum of all areas

$$V = \frac{h}{3} \cdot (a^2 + a \cdot b + b^2) \qquad A = \text{square}$$

$$V \approx A_m \cdot h \qquad V \approx \left(\frac{a+b}{2}\right)^2 \cdot h \qquad A = \text{square}$$

$$V = \frac{h}{3}\left(A + \sqrt{A \cdot A_1} + A_1\right) \qquad A = \text{n-corner}$$

## Frustrum of a pyramid




## Cover area

$$A_M = \pi \cdot \frac{d+D}{2} \cdot s$$

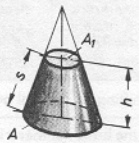
$$s = \sqrt{h^2 + (R-r)^2}$$

## Total surface area

$$A_O = A + A_1 + A_M$$

$$V = \frac{\pi}{12} \cdot h \cdot (D^2 + D \cdot d + d^2) \qquad \frac{\pi}{12} = 0{,}261$$

## Frustrum of a cone




## Surface area

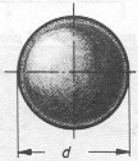
$$A_O = \pi \cdot d^2$$

$$V = \frac{2}{3} \cdot \frac{\pi}{4} \cdot d^2 \cdot d$$

$$V = \frac{\pi}{6} \cdot d^3$$

$$V = 0{,}5236 \cdot d^3$$

## Sphere




## Cover area

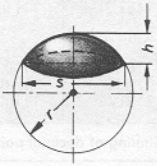
$$A_M = 2 \cdot \pi \cdot r \cdot h$$

$$A_M = \frac{\pi}{4}\left(s^2 + 4h^2\right)$$

$$V = \pi \cdot h^2 \cdot \left(r - \frac{h}{3}\right)$$

$$V = \pi \cdot h \left(\frac{s^2}{8} + \frac{h^2}{6}\right)$$

## Spherical segment




## Cover area

$$A_M = l \cdot \pi \cdot d_{s2}$$

## Surface area

$$A_O = U_A \cdot \pi \cdot d_{s1}$$

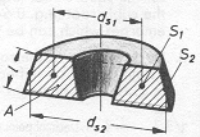
$U_A$ = Periphery of surface

## Guldin's law

$V$ = generating surface · centre of gravity path
$M$ = generating edge · centre of gravity path
$S$ = centre of gravity

$$V = A \cdot \pi \cdot d_{s1}$$

## Solids of revolution



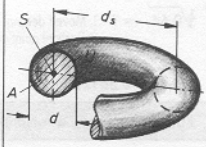

## Surface area
## Cover area

$$A_O = A_M = U \cdot \pi \cdot d_s$$

$$A_O = \pi \cdot d \cdot \pi \cdot d_s$$

$$V = \frac{\pi}{4} \cdot d^2 \cdot \pi \cdot d_s$$

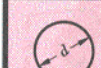
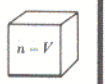
## Circular ring



# Arithmetical table

**Usage of the tables**

Meaning of numbers (tabulated value)
$d$ or $n$ is an arbitrary, known numerical figure e.g. **376** with which the computations should be carried out.

|  $\pi \cdot d$ | $\frac{\pi}{4} \cdot d^2$ | $n^2$ | $n^3$ | Number $d$ or $n$ | $\sqrt{n}$ |  $\sqrt[3]{n}$ |
|---|---|---|---|---|---|---|
| 1181.2 Circumference of a circle if $d = 376$ (mm, cm) | 111 036 Area of a circle, if $d = 376$ (mm, cm) | 141 376 Area of a square, if $n = 376$ (mm, cm) | 53 157 376 Volume of a cube, if $n = 376$ (mm, cm) | 376 | 19.3907 Side length of a square, if $A = 376$ ($mm^2$, $cm^2$) | 7.2177 Side length of a cube, if $V = 376$ ($mm^3$, $cm^3$) |

Shifting of decimal point for numbers which are not mentioned in the tables.

If the basic number $n$ is not 376, but 37.6 or 3760, then the decimal point must also be shiftet in the result i.e., in the tabulated. If the decimal point when compared with the tabulated value is one place left or right of the basic number,

then the decimal point should be shifted by

| 1 place | 2 places | 2 places | 3 places |
|---|---|---|---|

| $\pi \cdot d$ | $\frac{\pi}{4} \cdot d^2$ | $n^2$ | $n^3$ | Number $d$ or $n$ | |
|---|---|---|---|---|---|
| 1 | 2 | 2 | 3 | 1 | |
| 1181,2 | 111 036 | 141 376 | 53 157 376 | 376 | |
| | | | | Examples | Compared with the tabulated value 376, the decimal point is |
| 118,12 | 1110,36 | 1413,76 | 53157,376 | 37,6 | 1 place to the left |
| 11,812 | 11,1036 | 14,1376 | 53,157376 | 3,76 | 2 places to the left |
| 11812 | 11103600 | 14137600 | 53157376000 | 3760 | 1 place to the right |

Shifting of decimal point for determining roots of numbers which are not mentioned in the table.

Example: $\sqrt{3.7} = ?$ $\quad \sqrt[3]{0.64} = ?$

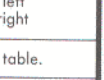
1. Move the decimal point in the basic number $n$, 2 places for the square root (e.g. 3.7 becomes 370) 3 places for the cubic root (e.g. 0.64 becomes 640) till a number emerges which can be found in the n column.
2. Decimal point of the root value found in $\sqrt{n}$- o. $\sqrt[3]{n}$-columns must be shifted back by one place (e.g. 19.2354 becomes 1.92354)

$\sqrt{3.7} = ?$ 1. Decimal point moves by 2 places $n = 3.7$ becomes → 2. Decimal point moved back one place, 19.2354 becomes 1.92354

$\sqrt{3.7} = 1.92354$

$\sqrt[3]{0.64} = ?$ 1. Moved decimal point 3 places $n = 0{,}64$ becomes → 2. Decimal point moved back one place 8.6177 becomes 0.86177

$\sqrt[3]{0.64} = 0.86177$

| $\sqrt{n}$ |  $\sqrt[3]{n}$ |
|---|---|
| Number $d$ or $n$ | |
| 1 | 1/2 | 1/3 |
| 370 | 19.2354 | |
| 640 | | 8.6177 |

Prime numbers and factors of the basic numbers $n$ are used for reduction in case of fractions.

# Logarithm

**Usage of numerical tables**

Logarithm is the second inversion of the process of raising a number to a power.

| Raising a number to a higher power | 1 Inversion taking the root | 2 Inversion taking the logarithm |
|---|---|---|
| $5^3 = 125$ | $\sqrt[3]{125} = 5$ | $^5\lg 125 = 3$ |

3 = the logarithm of the number 125 to the base 5

The lg-column of the numerical tables gives the Brigg's (or common) logarithm (lg) to the base 10.
In this case the logarithm of a number is an exponent (high number) to the base (basic number) 10.

e.g. $\lg 1000 = 3.0000$ as $10^{3.0000} = 1000$ 3.0000 = logarithm of 1000

Each logarithm of a number consists of a characteristic and the mantissa

number — logarithm

$\lg\ 4\,8\,3 = 2.6839$

characteristics — mantissa

The mantissa can be taken from the numerical table or logarithmic table. The characteristics is to be added. It is obtained from the digit of the given number (the position of the decimal point). For integers from 1 to 1000, as listed in the column 'lg' the characteristic has already been given.

## Finding the characteristic

| Let the number be $n$ | then the characteristic is | Examples: number $n$ | Examples: lg $n$ | |
|---|---|---|---|---|
| 4 places | 3,... one less | 4830 | 3.6839 | Equal digits 483 4.83 |
| 3 places | 2,... than the | 483 | 2.6839 | 0.0483 have the same |
| 2 places | 1,... number of | 48.3 | 1.6839 | mantissa .6839. |
| 1 place | 0,... digits before the decimal pt. | 4.83 | 0.6839 | The logarithm of these numbers differ from |
| 0,... 1 nought | 0,... −1 negative and | 0.483 | 0.6839−1 | one another in their |
| 0,0... 2 noughts | 0,... −2 equal to the | 0.0483 | 0.6839−2 | characteristics only. |
| 0,00... 3 noughts | 0,... −3 number of noughts | 0.00483 | 0.6839−3 | |

## Computation rules

**a · b** Multiplication is reduced to addition

$\lg(a \cdot b) = \lg a + \lg b$

$49.1 \cdot 3.47$

$\lg 49.1 = 1.6911$
$+ \lg 3.47 = 0.5403$
$2.2314$

$49.1 \cdot 3.47 = 170.38$

Mantissa .2314 number under column lg searched it gives for

| lg | n |
|---|---|
| 2304 | 170 |

2304 the number n : 170
for characteristic 2 : 170
after interpolation [1] : 170.38

**a : b** Division is reduced to subtraction

$\lg(a : b) = \lg a - \lg b$

$3.47 : 49.1$

$\lg 3.47 = 0.5403$
$- \lg 49.1 = 1.6911$
$0.8492 - 2$

$3.47 : 49.1 = 0.07067$

Mantissa .8492 in column lg shows at

| lg | n |
|---|---|
| 8494 | 707 |

8494 the number n : 707
for characteristic 0,...−2 : 0.0707
after interpolation [1] : 0.070666

**$a^n$** Raising a number to a higher power is reduced to multiplication

$\lg(a^n) = n \cdot \lg a$

$16^3$

$\lg 16 = 1.2041$
$3 \cdot \lg 16 = 3.6123$

$16^3 = 4096$

Mantissa .6123 in column lg shows at

| lg | n |
|---|---|
| 6117 | 409 |

6117 the number n : 409
For characteristic 3 : 4090
after interpolation [1] : 4096

**$\sqrt[n]{a}$** Finding the root is reduced to division

$\lg \sqrt[n]{a} = \frac{1}{n} \cdot \lg a$

$\sqrt[3]{145}$

$\frac{1}{3} \cdot \lg 145 = 2.1614$
$\lg 145 = 0.72047$

$\sqrt[3]{145} = 5.2534$

Mantissa .72047 in column lg shows at

| lg | n |
|---|---|
| 7202 | 525 |

7202 the number n : 525
For characteristic 0 : 5.25
after interpolation [1] : 5.2534

[1] for interpolation see next page

# Interpolation

Finding the proportional part of the difference between the calculated values shown in the tables can be performed with sufficient accuracy assuming that the listed values increase uniformly in approximate-linear fashion.

360,1 | $\pi \cdot 360{,}1 = ?$

| $n$ | $\pi \cdot n$ | |
|---|---|---|
| 360 | 1131,0 | } 3,1 difference |
| 361 | 1134,1 | |

1,0 ≙ 3,1

0,1 ≙ 0,1 · 3,1 = 0,31

$\pi \cdot 360{,}1 = 1131{,}0 + 0{,}31 =$ **1131,31**

means corresponds to

| $n$ | $\pi \cdot n$ | |
|---|---|---|
| 360 | 1131,0 | ← difference 3,1 → |
| ,1 | 1131,0 + 0,1 · 3,1 | = 1131,31 |
| ,2 | 1131,0 + 0,2 · 3,1 | = 1131,62 |
| ,3 | 1131,0 + 0,3 · 3,1 | = 1131,93 |
| ,4 | | |
| ,5 | | |
| ,6 | | |
| ,65 | 1131,0 + 0,65 · 3,1 | = 1133,02 |
| ,7 | | |
| ,8 | | |
| ,9 | 1131,0 + 0,9 · 3,1 | = 1133,79 |
| 361 | 1134,1 | |

200,25 | $\frac{\pi}{4} \cdot 200{,}25 = ?$

| $n$ | $\frac{\pi}{4} \cdot n$ | |
|---|---|---|
| 200 | 31415,9 | } 315 difference |
| 201 | 31730,9 | |

1,00 ≙ 315,0

0,25 ≙ 0,25 · 315,0 = 78,75

$\frac{\pi}{4} \cdot 200{,}25 = 31415{,}9 + 78{,}75 = 31494{,}65$

170,27 | $170{,}27^2 = ?$

| $n$ | $n^2$ | |
|---|---|---|
| 170 | 28900 | } 341 difference |
| 171 | 29241 | |

1,0 ≙ 341

0,27 ≙ 0,27 · 341 = 92,07

$170{,}27^2 = 28900 + 92{,}07 =$ **28992,07**

170,27 | $170{,}27^3 = ?$

| $n$ | $n^3$ | |
|---|---|---|
| 170 | 4913000 | } 87211 difference |
| 171 | 5000211 | |

1,0 ≙ 87211

0,27 ≙ 0,27 · 87211 = 23547

$170{,}27^3 = 4913000 + 23547 =$ **4936547**

$\sqrt{n}$

45,67 | $\sqrt{45{,}67} = ?$

| $n$ | $\sqrt{n}$ | |
|---|---|---|
| 45 | 6,7082 | } 0,0741 difference |
| 46 | 6,7823 | |

Units of the fourth decimal

1,0 ≙ 0,0741

0,67 ≙ 0,67 · 741 = 496,47

$\sqrt{45{,}67} = 6{,}7082 + 0{,}0496 =$ **6,7578**

$\sqrt[3]{n}$

687,63 | $\sqrt[3]{687{,}63} = ?$

| $n$ | $\sqrt[3]{n}$ | |
|---|---|---|
| 687 | 8,8237 | } 0,0043 difference |
| 688 | 8,8280 | |

Units of the fourth decimal

1,0 ≙ 0,0043

0,63 ≙ 0,63 · 43 = 27,09

$\sqrt[3]{687{,}63} = 8{,}8237 + 27{,}09 =$ **8,8264**

lg

825,65 | $\lg 825{,}65 = ?$

| $n$ | $\lg n$ | |
|---|---|---|
| 825 | 2,9165 | } 0,0005 difference |
| 826 | 2,9170 | |

1 ≙ 5

0,65 ≙ 0,65 · 5 = 3,25

$\lg 825{,}65$ 2,9165

+ 325

= **2,916825**

lg

2,2314 | $n = ?$

| $\lg n$ | $n$ |
|---|---|
| 2,2304 | 170 |
| 2,2330 | 171 |

26 ≙ 1

1 ≙ 1 : 26 = 0,038

10 ≙ 0,38

2,2314 170

+ 0,38

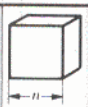
= **170,38**

**Inverse calculation:** As one usually starts in column n to find the needed values, one can do likewise the opposite:

e.g. $\sqrt{36480} = ?$ For 36481 in column $n^2$ the column $n$ gives the value 191. So $\sqrt{36480} = 191$

| A given number $z$ in column: | $\pi \cdot d$ | $\frac{\pi}{4} \cdot d^2$ | $n^2$ | $n^3$ | $\sqrt{n}$ | $\sqrt[3]{n}$ |
|---|---|---|---|---|---|---|
| results in column $n$ : | $d$ | $d$ | $\sqrt{z}$ | $\sqrt[3]{z}$ | $z^2$ | $z^3$ |

# Mathematical tables

| $C = \pi \cdot d$ | $A = \frac{\pi \cdot d^2}{4}$ | $A = n^2$ |  $V = n^3$ | Number $d$ or $n$ | $\sqrt{n}$ | $\sqrt[3]{n}$ | Factors and primes | lg $n$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 2 | 3 | | $\frac{1}{2}$ | $\frac{1}{3}$ | — | — |
| 3,142 | 0,7854 | 1 | 1 | 1 | 1,0000 | 1,0000 | — | 0,0000 |
| 6,283 | 3,1416 | 4 | 8 | 2 | 1,4142 | 1,2599 | — | 0,3010 |
| 9,425 | 7,0686 | 9 | 27 | 3 | 1,7321 | 1,4422 | — | 0,4771 |
| 12,566 | 12,5664 | 16 | 64 | 4 | 2,0000 | 1,5874 | $2^2$ | 0,6021 |
| 15,708 | 19,6350 | 25 | 125 | 5 | 2,2361 | 1,7100 | — | 0,6990 |
| 18,850 | 28,2743 | 36 | 216 | 6 | 2,4495 | 1,8171 | $2 \cdot 3$ | 0,7782 |
| 21,991 | 38,4845 | 49 | 343 | 7 | 2,6458 | 1,9129 | — | 0,8451 |
| 25,133 | 50,2655 | 64 | 512 | 8 | 2,8284 | 2,0000 | $2^3$ | 0,9031 |
| 28,274 | 63,6173 | 81 | 729 | 9 | 3,0000 | 2,0801 | $3^2$ | 0,9542 |
| 31,416 | 78,5398 | 100 | 1000 | 10 | 3,1623 | 2,1544 | $2 \cdot 5$ | 1,0000 |
| 34,558 | 95,0332 | 121 | 1331 | 11 | 3,3166 | 2,2240 | — | 1,0414 |
| 37,699 | 113,097 | 144 | 1728 | 12 | 3,4641 | 2,2894 | $2^2 \cdot 3$ | 1,0792 |
| 40,841 | 132,732 | 169 | 2197 | 13 | 3,6056 | 2,3513 | — | 1,1139 |
| 43,982 | 153,938 | 196 | 2744 | 14 | 3,7417 | 2,4101 | $2 \cdot 7$ | 1,1461 |
| 47,124 | 176,715 | 225 | 3375 | 15 | 3,8730 | 2,4662 | $3 \cdot 5$ | 1,1761 |
| 50,265 | 201,062 | 256 | 4096 | 16 | 4,0000 | 2,5198 | $2^4$ | 1,2041 |
| 53,407 | 226,980 | 289 | 4913 | 17 | 4,1231 | 2,5713 | — | 1,2305 |
| 56,549 | 254,469 | 324 | 5832 | 18 | 4,2426 | 2,6207 | $2 \cdot 3^2$ | 1,2553 |
| 59,690 | 283,529 | 361 | 6859 | 19 | 4,3589 | 2,6684 | — | 1,2788 |
| 62,832 | 314,159 | 400 | 8000 | 20 | 4,4721 | 2,7144 | $2^2 \cdot 5$ | 1,3010 |
| 65,973 | 346,361 | 441 | 9261 | 21 | 4,5826 | 2,7589 | $3 \cdot 7$ | 1,3222 |
| 69,115 | 380,133 | 484 | 10648 | 22 | 4,6904 | 2,8020 | $2 \cdot 11$ | 1,3424 |
| 72,257 | 415,476 | 529 | 12167 | 23 | 4,7958 | 2,8439 | — | 1,3617 |
| 75,398 | 452,389 | 576 | 13824 | 24 | 4,8990 | 2,8845 | $2^3 \cdot 3$ | 1,3802 |
| 78,540 | 490,874 | 625 | 15625 | 25 | 5,0000 | 2,9240 | $5^2$ | 1,3980 |
| 81,681 | 530,929 | 676 | 17576 | 26 | 5,0990 | 2,9625 | $2 \cdot 13$ | 1,4150 |
| 84,823 | 572,555 | 729 | 19683 | 27 | 5,1962 | 3,0000 | $3^3$ | 1,4314 |
| 87,965 | 615,752 | 784 | 21952 | 28 | 5,2915 | 3,0366 | $2^2 \cdot 7$ | 1,4472 |
| 91,106 | 660,520 | 841 | 24389 | 29 | 5,3852 | 3,0723 | — | 1,4624 |
| 94,248 | 706,858 | 900 | 27000 | 30 | 5,4772 | 3,1072 | $2 \cdot 3 \cdot 5$ | 1,4771 |
| 97,389 | 754,768 | 961 | 29791 | 31 | 5,5678 | 3,1414 | — | 1,4914 |
| 100,531 | 804,248 | 1024 | 32768 | 32 | 5,6569 | 3,1748 | $2^5$ | 1,5052 |
| 103,673 | 855,299 | 1089 | 35937 | 33 | 5,7446 | 3,2075 | $3 \cdot 11$ | 1,5185 |
| 106,814 | 907,920 | 1156 | 39304 | 34 | 5,8310 | 3,2396 | $2 \cdot 17$ | 1,5315 |
| 109,956 | 962,113 | 1225 | 42875 | 35 | 5,9161 | 3,2711 | $5 \cdot 7$ | 1,5441 |
| 113,097 | 1017,88 | 1296 | 46656 | 36 | 6,0000 | 3,3019 | $2^2 \cdot 3^2$ | 1,5563 |
| 116,239 | 1075,21 | 1369 | 50653 | 37 | 6,0828 | 3,3322 | — | 1,5682 |
| 119,381 | 1134,11 | 1444 | 54872 | 38 | 6,1644 | 3,3620 | $2 \cdot 19$ | 1,5798 |
| 122,522 | 1194,59 | 1521 | 59319 | 39 | 6,2450 | 3,3912 | $3 \cdot 13$ | 1,5911 |
| 125,66 | 1256,64 | 1600 | 64000 | 40 | 6,3246 | 3,4200 | $2^3 \cdot 5$ | 1,6021 |
| 128,81 | 1320,25 | 1681 | 68921 | 41 | 6,4031 | 3,4482 | — | 1,6128 |
| 131,95 | 1385,44 | 1764 | 74088 | 42 | 6,4807 | 3,4760 | $2 \cdot 3 \cdot 7$ | 1,6233 |
| 135,09 | 1452,20 | 1849 | 79507 | 43 | 6,5574 | 3,5034 | — | 1,6335 |
| 138,23 | 1520,53 | 1936 | 85184 | 44 | 6,6332 | 3,5303 | $2^2 \cdot 11$ | 1,6435 |
| 141,37 | 1590,43 | 2025 | 91125 | 45 | 6,7082 | 3,5569 | $3^2 \cdot 5$ | 1,6532 |
| 144,51 | 1661,90 | 2116 | 97336 | 46 | 6,7823 | 3,5830 | $2 \cdot 23$ | 1,6628 |
| 147,65 | 1734,94 | 2209 | 103823 | 47 | 6,8557 | 3,6088 | — | 1,6721 |
| 150,80 | 1809,56 | 2304 | 110592 | 48 | 6,9282 | 3,6342 | $2^4 \cdot 3$ | 1,6812 |
| 153,94 | 1885,74 | 2401 | 117649 | 49 | 7,0000 | 3,6593 | $7^2$ | 1,6902 |
| 157,08 | 1963,50 | 2500 | 125000 | 50 | 7,0711 | 3,6840 | $2 \cdot 5^2$ | 1,6990 |

1 ... 50

$C = \pi \cdot d$




$A = \frac{\pi \cdot d^2}{4}$




$A = n^2$




$V = n^3$

Number $d$ or $n$




$\sqrt{n}$




$\sqrt[3]{n}$

Factors and primes

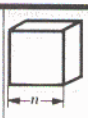
lg $n$

| 1 | 2 | 2 | 3 | | $\frac{1}{2}$ | $\frac{1}{3}$ | — | — |
|---|---|---|---|---|---|---|---|---|
| 160,22 | 2042,82 | 2601 | 132651 | 51 | 7,1414 | 3,7084 | $3 \cdot 17$ | 1,7076 |
| 163,36 | 2123,72 | 2704 | 140608 | 52 | 7,2111 | 3,7325 | $2^2 \cdot 13$ | 1,7160 |
| 166,50 | 2206,18 | 2809 | 148877 | 53 | 7,2801 | 3,7563 | — | 1,7243 |
| 169,65 | 2290,22 | 2916 | 157464 | 54 | 7,3485 | 3,7798 | $2 \cdot 3^3$ | 1,7324 |
| 172,79 | 2375,83 | 3025 | 166375 | 55 | 7,4162 | 3,8030 | $5 \cdot 11$ | 1,7404 |
| 175,93 | 2463,01 | 3136 | 175616 | 56 | 7,4833 | 3,8259 | $2^3 \cdot 7$ | 1,7482 |
| 179,07 | 2551,76 | 3249 | 185193 | 57 | 7,5498 | 3,8485 | $3 \cdot 19$ | 1,7559 |
| 182,21 | 2642,08 | 3364 | 195112 | 58 | 7,6158 | 3,8709 | $2 \cdot 29$ | 1,7634 |
| 185,35 | 2733,97 | 3481 | 205379 | 59 | 7,6811 | 3,8930 | — | 1,7709 |
| 188,50 | 2827,43 | 3600 | 216000 | 60 | 7,7460 | 3,9149 | $2^2 \cdot 3 \cdot 5$ | 1,7782 |
| 191,64 | 2922,47 | 3721 | 226981 | 61 | 7,8102 | 3,9365 | — | 1,7853 |
| 194,78 | 3019,07 | 3844 | 238328 | 62 | 7,8740 | 3,9579 | $2 \cdot 31$ | 1,7924 |
| 197,92 | 3117,25 | 3969 | 250047 | 63 | 7,9373 | 3,9791 | $3^2 \cdot 7$ | 1,7993 |
| 201,06 | 3216,99 | 4096 | 262144 | 64 | 8,0000 | 4,0000 | $2^6$ | 1,8062 |
| 204,20 | 3318,31 | 4225 | 274625 | 65 | 8,0623 | 4,0207 | $5 \cdot 13$ | 1,8129 |
| 207,35 | 3421,19 | 4356 | 287496 | 66 | 8,1240 | 4,0412 | $2 \cdot 3 \cdot 11$ | 1,8195 |
| 210,49 | 3525,65 | 4489 | 300763 | 67 | 8,1854 | 4,0615 | — | 1,8261 |
| 213,63 | 3631,68 | 4624 | 314432 | 68 | 8,2462 | 4,0817 | $2^2 \cdot 17$ | 1,8325 |
| 216,77 | 3739,28 | 4761 | 328509 | 69 | 8,3066 | 4,1016 | $3 \cdot 23$ | 1,8389 |
| 219,91 | 3848,45 | 4900 | 343000 | 70 | 8,3666 | 4,1213 | $2 \cdot 5 \cdot 7$ | 1,8451 |
| 223,05 | 3959,19 | 5041 | 357911 | 71 | 8,4261 | 4,1408 | — | 1,8513 |
| 226,19 | 4071,50 | 5184 | 373248 | 72 | 8,4853 | 4,1602 | $2^3 \cdot 3^2$ | 1,8573 |
| 229,34 | 4185,39 | 5329 | 389017 | 73 | 8,5440 | 4,1793 | — | 1,8633 |
| 232,48 | 4300,84 | 5476 | 405224 | 74 | 8,6023 | 4,1983 | $2 \cdot 37$ | 1,8692 |
| 235,62 | 4417,86 | 5625 | 421875 | 75 | 8,6603 | 4,2172 | $3 \cdot 5^3$ | 1,8751 |
| 238,76 | 4536,46 | 5776 | 438976 | 76 | 8,7178 | 4,2358 | $2^2 \cdot 19$ | 1,8808 |
| 241,90 | 4656,63 | 5929 | 456533 | 77 | 8,7750 | 4,2543 | $7 \cdot 11$ | 1,8865 |
| 245,04 | 4778,36 | 6084 | 474552 | 78 | 8,8318 | 4,2727 | $2 \cdot 3 \cdot 13$ | 1,8921 |
| 248,19 | 4901,67 | 6241 | 493039 | 79 | 8,8882 | 4,2908 | — | 1,8976 |
| 251,33 | 5026,55 | 6400 | 512000 | 80 | 8,9443 | 4,3089 | $2^4 \cdot 5$ | 1,9031 |
| 254,47 | 5153,00 | 6561 | 531441 | 81 | 9,0000 | 4,3267 | $3^4$ | 1,9085 |
| 257,61 | 5281,02 | 6724 | 551368 | 82 | 9,0554 | 4,3445 | $2 \cdot 41$ | 1,9138 |
| 260,75 | 5410,61 | 6889 | 571787 | 83 | 9,1104 | 4,3621 | — | 1,9191 |
| 263,89 | 5541,77 | 7056 | 592704 | 84 | 9,1652 | 4,3795 | $2^2 \cdot 3 \cdot 7$ | 1,9243 |
| 267,04 | 5674,50 | 7225 | 614125 | 85 | 9,2195 | 4,3968 | $5 \cdot 17$ | 1,9294 |
| 270,18 | 5808,80 | 7396 | 636056 | 86 | 9,2736 | 4,4140 | $2 \cdot 43$ | 1,9345 |
| 273,32 | 5944,68 | 7569 | 658503 | 87 | 9,3274 | 4,4310 | $3 \cdot 29$ | 1,9395 |
| 276,46 | 6082,12 | 7744 | 681472 | 88 | 9,3808 | 4,4480 | $2^3 \cdot 11$ | 1,9445 |
| 279,60 | 6221,14 | 7921 | 704969 | 89 | 9,4340 | 4,4647 | — | 1,9494 |
| 282,74 | 6361,73 | 8100 | 729000 | 90 | 9,4868 | 4,4814 | $2 \cdot 3^2 \cdot 5$ | 1,9542 |
| 285,88 | 6503,88 | 8281 | 753571 | 91 | 9,5394 | 4,4979 | $7 \cdot 13$ | 1,9590 |
| 289,03 | 6647,61 | 8464 | 778688 | 92 | 9,5917 | 4,5144 | $2^2 \cdot 23$ | 1,9638 |
| 292,17 | 6792,91 | 8649 | 804357 | 93 | 9,6437 | 4,5307 | $3 \cdot 31$ | 1,9685 |
| 295,31 | 6939,78 | 8836 | 830584 | 94 | 9,6954 | 4,5468 | $2 \cdot 47$ | 1,9731 |
| 298,45 | 7088,22 | 9025 | 857375 | 95 | 9,7468 | 4,5629 | $5 \cdot 19$ | 1,9777 |
| 301,59 | 7238,23 | 9216 | 884736 | 96 | 9,7980 | 4,5789 | $2^5 \cdot 3$ | 1,9823 |
| 304,73 | 7389,81 | 9409 | 912673 | 97 | 9,8489 | 4,5947 | — | 1,9868 |
| 307,88 | 7542,96 | 9604 | 941192 | 98 | 9,8995 | 4,6104 | $2 \cdot 7^2$ | 1,9912 |
| 311,02 | 7697,69 | 9801 | 970299 | 99 | 9,9499 | 4,6261 | $3^2 \cdot 11$ | 1,9956 |
| 314,16 | 7853,98 | 10000 | 1000000 | 100 | 10,0000 | 4,6416 | $2^2 \cdot 5^2$ | 2,0000 |

51 ... 100

| $C = \pi \cdot d$ | $A = \frac{\pi \cdot d^2}{4}$ | $A = n^2$ | $V = n^3$ | Number $d$ or $n$ | $n$ $\sqrt{n}$ | $n$ $\sqrt[3]{n}$ | Factors and primes | $\lg n$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 2 | 3 | | $\frac{1}{2}$ | $\frac{1}{3}$ | — | — |
| 317,30 | 8011,85 | 10201 | 1030301 | 101 | 10,0499 | 4,6570 | — | 2,0043 |
| 320,44 | 8171,28 | 10404 | 1061208 | 102 | 10,0995 | 4,6723 | $2 \cdot 3 \cdot 17$ | 2,0086 |
| 323,58 | 8332,29 | 10609 | 1092727 | 103 | 10,1489 | 4,6875 | — | 2,0128 |
| 326,73 | 8494,87 | 10816 | 1124864 | 104 | 10,1980 | 4,7027 | $2^2 \cdot 13$ | 2,0170 |
| 329,87 | 8659,01 | 11025 | 1157625 | 105 | 10,2470 | 4,7177 | $3 \cdot 5 \cdot 7$ | 2,0212 |
| 333,01 | 8824,73 | 11236 | 1191016 | 106 | 10,2956 | 4,7326 | $2 \cdot 53$ | 2,0253 |
| 336,15 | 8992,02 | 11449 | 1225043 | 107 | 10,3441 | 4,7475 | — | 2,0294 |
| 339,29 | 9160,88 | 11664 | 1259712 | 108 | 10,3923 | 4,7622 | $2^2 \cdot 3^2$ | 2,0334 |
| 342,43 | 9331,32 | 11881 | 1295029 | 109 | 10,4403 | 4,7769 | — | 2,0374 |
| 345,58 | 9503,32 | 12100 | 1331000 | 110 | 10,4881 | 4,7914 | $2 \cdot 5 \cdot 11$ | 2,0414 |
| 348,72 | 9676,89 | 12321 | 1367631 | 111 | 10,5357 | 4,8059 | $3 \cdot 37$ | 2,0453 |
| 351,86 | 9852,03 | 12544 | 1404928 | 112 | 10,5830 | 4,8203 | $2^4 \cdot 7$ | 2,0492 |
| 355,00 | 10028,7 | 12769 | 1442897 | 113 | 10,6301 | 4,8346 | — | 2,0531 |
| 358,14 | 10207,0 | 12996 | 1481544 | 114 | 10,6771 | 4,8488 | $2 \cdot 3 \cdot 19$ | 2,0569 |
| 361,28 | 10386,9 | 13225 | 1520875 | 115 | 10,7238 | 4,8629 | $5 \cdot 23$ | 2,0607 |
| 364,42 | 10568,3 | 13456 | 1560896 | 116 | 10,7703 | 4,8770 | $2^2 \cdot 29$ | 2,0645 |
| 367,57 | 10751,3 | 13689 | 1601613 | 117 | 10,8167 | 4,8910 | $3^2 \cdot 13$ | 2,0682 |
| 370,71 | 10935,9 | 13924 | 1643032 | 118 | 10,8628 | 4,9049 | $2 \cdot 59$ | 2,0719 |
| 373,85 | 11122,0 | 14161 | 1685159 | 119 | 10,9087 | 4,9187 | $7 \cdot 17$ | 2,0756 |
| 376,99 | 11309,7 | 14400 | 1728000 | 120 | 10,9545 | 4,9324 | $2^3 \cdot 3 \cdot 5$ | 2,0792 |
| 380,13 | 11499,0 | 14641 | 1771561 | 121 | 11,0000 | 4,9461 | $11^2$ | 2,0828 |
| 383,27 | 11689,9 | 14884 | 1815848 | 122 | 11,0454 | 4,9597 | $2 \cdot 61$ | 2,0864 |
| 386,42 | 11882,3 | 15129 | 1860867 | 123 | 11,0905 | 4,9732 | $3 \cdot 41$ | 2,0899 |
| 389,56 | 12076,3 | 15376 | 1906624 | 124 | 11,1355 | 4,9866 | $2^2 \cdot 31$ | 2,0934 |
| 392,70 | 12271,8 | 15625 | 1953125 | 125 | 11,1803 | 5,0000 | $5^3$ | 2,0969 |
| 395,84 | 12469,0 | 15876 | 2000376 | 126 | 11,2250 | 5,0133 | $2 \cdot 3^2 \cdot 7$ | 2,1004 |
| 398,98 | 12667,7 | 16129 | 2048383 | 127 | 11,2694 | 5,0265 | — | 2,1038 |
| 402,12 | 12868,0 | 16384 | 2097152 | 128 | 11,3137 | 5,0397 | $2^7$ | 2,1072 |
| 405,27 | 13069,8 | 16641 | 2146689 | 129 | 11,3578 | 5,0528 | $3 \cdot 43$ | 2,1106 |
| 408,41 | 13273,2 | 16900 | 2197000 | 130 | 11,4018 | 5,0658 | $2 \cdot 5 \cdot 13$ | 2,1139 |
| 411,55 | 13478,2 | 17161 | 2248091 | 131 | 11,4455 | 5,0788 | — | 2,1173 |
| 414,69 | 13684,8 | 17424 | 2299968 | 132 | 11,4891 | 5,0916 | $2^2 \cdot 3 \cdot 11$ | 2,1206 |
| 417,83 | 13892,9 | 17689 | 2352637 | 133 | 11,5326 | 5,1045 | $7 \cdot 19$ | 2,1239 |
| 420,97 | 14102,6 | 17956 | 2406104 | 134 | 11,5758 | 5,1172 | $2 \cdot 67$ | 2,1271 |
| 424,12 | 14313,9 | 18225 | 2460375 | 135 | 11,6190 | 5,1299 | $3^3 \cdot 5$ | 2,1303 |
| 427,26 | 14526,7 | 18496 | 2515456 | 136 | 11,6619 | 5,1426 | $2^3 \cdot 17$ | 2,1335 |
| 430,40 | 14741,1 | 18769 | 2571353 | 137 | 11,7047 | 5,1551 | — | 2,1367 |
| 433,54 | 14957,1 | 19044 | 2628072 | 138 | 11,7473 | 5,1676 | $2 \cdot 3 \cdot 23$ | 2,1399 |
| 436,68 | 15174,7 | 19321 | 2685619 | 139 | 11,7898 | 5,1801 | — | 2,1430 |
| 439,82 | 15393,8 | 19600 | 2744000 | 140 | 11,8322 | 5,1925 | $2^2 \cdot 5 \cdot 7$ | 2,1461 |
| 442,96 | 15614,5 | 19881 | 2803221 | 141 | 11,8743 | 5,2048 | $3 \cdot 47$ | 2,1492 |
| 446,11 | 15836,8 | 20164 | 2863288 | 142 | 11,9164 | 5,2171 | $2 \cdot 71$ | 2,1523 |
| 449,25 | 16060,6 | 20449 | 2924207 | 143 | 11,9583 | 5,2293 | $11 \cdot 13$ | 2,1553 |
| 452,39 | 16286,0 | 20736 | 2985984 | 144 | 12,0000 | 5,2415 | $2^4 \cdot 3^2$ | 2,1584 |
| 455,53 | 16513,0 | 21025 | 3048625 | 145 | 12,0416 | 5,2536 | $5 \cdot 29$ | 2,1614 |
| 458,67 | 16741,5 | 21316 | 3112136 | 146 | 12,0830 | 5,2656 | $2 \cdot 73$ | 2,1644 |
| 461,81 | 16971,7 | 21609 | 3176523 | 147 | 12,1244 | 5,2776 | $3 \cdot 7^2$ | 2,1673 |
| 464,96 | 17203,4 | 21904 | 3241792 | 148 | 12,1655 | 5,2896 | $2^2 \cdot 37$ | 2,1703 |
| 468,10 | 17436,6 | 22201 | 3307949 | 149 | 12,2066 | 5,3015 | — | 2,1732 |
| 471,24 | 17671,5 | 22500 | 3375000 | 150 | 12,2474 | 5,3133 | $2 \cdot 3 \cdot 5^2$ | 2,1761 |

| $C = \pi \cdot d$ | $A = \frac{\pi \cdot d^2}{4}$ | $A = n^2$ | $V = n^3$ | Number $d$ or $n$ | $\sqrt{n}$ | $\sqrt[3]{n}$ | Factors and primes | lg $n$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 2 | 3 | | $\frac{1}{2}$ | $\frac{1}{3}$ | — | — |
| 474,38 | 17907,9 | 22801 | 3442951 | 151 | 12,2882 | 5,3251 | — | 2,1790 |
| 477,52 | 18145,8 | 23104 | 3511808 | 152 | 12,3288 | 5,3368 | $2^3 \cdot 19$ | 2,1818 |
| 480,66 | 18385,4 | 23409 | 3581577 | 153 | 12,3693 | 5,3485 | $3^3 \cdot 17$ | 2,1847 |
| 483,81 | 18626,5 | 23716 | 3652264 | 154 | 12,4097 | 5,3601 | $2 \cdot 7 \cdot 11$ | 2,1875 |
| 486,95 | 18869,2 | 24025 | 3723875 | 155 | 12,4499 | 5,3717 | $5 \cdot 31$ | 2,1903 |
| 490,09 | 19113,4 | 24336 | 3796416 | 156 | 12,4900 | 5,3832 | $2^2 \cdot 3 \cdot 13$ | 2,1931 |
| 493,23 | 19359,3 | 24649 | 3869893 | 157 | 12,5300 | 5,3947 | — | 2,1959 |
| 496,37 | 19606,7 | 24964 | 3944312 | 158 | 12,5698 | 5,4061 | $2 \cdot 79$ | 2,1987 |
| 499,51 | 19855,7 | 25281 | 4019679 | 159 | 12,6095 | 5,4175 | $3 \cdot 53$ | 2,2014 |
| 502,65 | 20106,2 | 25600 | 4096000 | 160 | 12,6491 | 5,4288 | $2^8 \cdot 5$ | 2,2041 |
| 505,80 | 20358,3 | 25921 | 4173281 | 161 | 12,6886 | 5,4401 | $7 \cdot 23$ | 2,2068 |
| 508,94 | 20612,0 | 26244 | 4251528 | 162 | 12,7279 | 5,4514 | $2 \cdot 3^4$ | 2,2095 |
| 512,08 | 20867,2 | 26569 | 4330747 | 163 | 12,7671 | 5,4626 | — | 2,2122 |
| 515,22 | 21124,1 | 26896 | 4410944 | 164 | 12,8062 | 5,4737 | $2^2 \cdot 41$ | 2,2148 |
| 518,36 | 21382,5 | 27225 | 4492125 | 165 | 12,8452 | 5,4848 | $3 \cdot 5 \cdot 11$ | 2,2175 |
| 521,50 | 21642,4 | 27556 | 4574296 | 166 | 12,8841 | 5,4959 | $2 \cdot 83$ | 2,2201 |
| 524,65 | 21904,0 | 27889 | 4657463 | 167 | 12,9229 | 5,5069 | — | 2,2227 |
| 527,79 | 22167,1 | 28224 | 4741632 | 168 | 12,9615 | 5,5178 | $2^3 \cdot 3 \cdot 7$ | 2,2253 |
| 530,93 | 22431,8 | 28561 | 4826809 | 169 | 13,0000 | 5,5288 | $13^2$ | 2,2279 |
| 534,07 | 22698,0 | 28900 | 4913000 | 170 | 13,0384 | 5,5397 | $2 \cdot 5 \cdot 17$ | 2,2305 |
| 537,21 | 22965,8 | 29241 | 5000211 | 171 | 13,0767 | 5,5505 | $3^2 \cdot 19$ | 2,2330 |
| 540,35 | 23235,2 | 29584 | 5088448 | 172 | 13,1149 | 5,5613 | $2^2 \cdot 43$ | 2,2355 |
| 543,50 | 23506,2 | 29929 | 5177717 | 173 | 13,1529 | 5,5721 | — | 2,2381 |
| 546,64 | 23778,7 | 30276 | 5268024 | 174 | 13,1909 | 5,5828 | $2 \cdot 3 \cdot 29$ | 2,2406 |
| 549,78 | 24052,8 | 30625 | 5359375 | 175 | 13,2288 | 5,5934 | $5^3 \cdot 7$ | 2,2430 |
| 552,92 | 24328,5 | 30976 | 5451776 | 176 | 13,2665 | 5,6041 | $2^4 \cdot 11$ | 2,2455 |
| 556,06 | 24605,7 | 31329 | 5545233 | 177 | 13,3041 | 5,6147 | $3 \cdot 59$ | 2,2480 |
| 559,20 | 24884,6 | 31684 | 5639752 | 178 | 13,3417 | 5,6252 | $2 \cdot 89$ | 2,2504 |
| 562,35 | 25164,9 | 32041 | 5735339 | 179 | 13,3791 | 5,6357 | — | 2,2529 |
| 565,49 | 25446,9 | 32400 | 5832000 | 180 | 13,4164 | 5,6462 | $2^3 \cdot 3^3 \cdot 5$ | 2,2553 |
| 568,63 | 25730,4 | 32761 | 5929741 | 181 | 13,4536 | 5,6567 | — | 2,2577 |
| 571,77 | 26015,5 | 33124 | 6028568 | 182 | 13,4907 | 5,6671 | $2 \cdot 7 \cdot 13$ | 2,2601 |
| 574,91 | 26302,2 | 33489 | 6128487 | 183 | 13,5277 | 5,6774 | $3 \cdot 61$ | 2,2625 |
| 578,05 | 26590,4 | 33856 | 6229504 | 184 | 13,5647 | 5,6877 | $2^3 \cdot 23$ | 2,2648 |
| 581,19 | 26880,3 | 34225 | 6331625 | 185 | 13,6015 | 5,6980 | $5 \cdot 37$ | 2,2672 |
| 584,34 | 27171,6 | 34596 | 6434856 | 186 | 13,6382 | 5,7083 | $2 \cdot 3 \cdot 31$ | 2,2695 |
| 587,48 | 27464,6 | 34969 | 6539203 | 187 | 13,6748 | 5,7185 | $11 \cdot 17$ | 2,2718 |
| 590,62 | 27759,1 | 35344 | 6644672 | 188 | 13,7113 | 5,7287 | $2^2 \cdot 47$ | 2,2742 |
| 593,76 | 28055,2 | 35721 | 6751269 | 189 | 13,7477 | 5,7388 | $3^3 \cdot 7$ | 2,2765 |
| 596,90 | 28352,9 | 36100 | 6859000 | 190 | 13,7840 | 5,7489 | $2 \cdot 5 \cdot 19$ | 2,2788 |
| 600,04 | 28652,1 | 36481 | 6967871 | 191 | 13,8203 | 5,7590 | — | 2,2810 |
| 603,19 | 28952,9 | 36864 | 7077888 | 192 | 13,8564 | 5,7690 | $2^6 \cdot 3$ | 2,2833 |
| 606,33 | 29255,3 | 37249 | 7189057 | 193 | 13,8924 | 5,7790 | — | 2,2856 |
| 609,47 | 29559,2 | 37636 | 7301384 | 194 | 13,9284 | 5,7890 | $2 \cdot 97$ | 2,2878 |
| 612,61 | 29864,8 | 38025 | 7414875 | 195 | 13,9642 | 5,7989 | $3 \cdot 5 \cdot 13$ | 2,2900 |
| 615,75 | 30171,9 | 38416 | 7529536 | 196 | 14,0000 | 5,8088 | $2^2 \cdot 7^2$ | 2,2923 |
| 618,89 | 30480,5 | 38809 | 7645373 | 197 | 14,0357 | 5,8186 | — | 2,2945 |
| 622,04 | 30790,7 | 39204 | 7762392 | 198 | 14,0712 | 5,8285 | $2 \cdot 3^3 \cdot 11$ | 2,2967 |
| 625,18 | 31102,6 | 39601 | 7880599 | 199 | 14,1067 | 5,8383 | — | 2,2989 |
| 628,32 | 31415,9 | 40000 | 8000000 | 200 | 14,1421 | 5,8480 | $2^3 \cdot 5^3$ | 2,3010 |

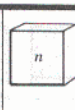
| $C = \pi \cdot d$ | $A = \frac{\pi \cdot d^2}{4}$ | $A = n^2$ |  $V = n^3$ | Number $d$ or $n$ | $\sqrt{n}$ | $\sqrt[3]{n}$ | Factors and primes | lg $n$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 2 | 3 | | $\frac{1}{2}$ | $\frac{1}{3}$ | — | — |
| 631,46 | 31730,9 | 40401 | 8120601 | 201 | 14,1774 | 5,8578 | $3 \cdot 67$ | 2,3032 |
| 634,60 | 32047,4 | 40804 | 8242408 | 202 | 14,2127 | 5,8675 | $2 \cdot 101$ | 2,3054 |
| 637,74 | 32365,5 | 41209 | 8365427 | 203 | 14,2478 | 5,8771 | $7 \cdot 29$ | 2,3075 |
| 640,88 | 32685,1 | 41616 | 8489664 | 204 | 14,2829 | 5,8868 | $2^2 \cdot 3 \cdot 17$ | 2,3096 |
| 644,03 | 33006,4 | 42025 | 8615125 | 205 | 14,3178 | 5,8964 | $5 \cdot 41$ | 2,3118 |
| 647,17 | 33329,2 | 42436 | 8741816 | 206 | 14,3527 | 5,9059 | $2 \cdot 103$ | 2,3139 |
| 650,31 | 33653,5 | 42849 | 8869743 | 207 | 14,3875 | 5,9155 | $3^2 \cdot 23$ | 2,3160 |
| 653,45 | 33979,5 | 43264 | 8998912 | 208 | 14,4222 | 5,9250 | $2^4 \cdot 13$ | 2,3181 |
| 656,59 | 34307,0 | 43681 | 9129329 | 209 | 14,4568 | 5,9345 | $11 \cdot 19$ | 2,3202 |
| 659,73 | 34636,1 | 44100 | 9261000 | 210 | 14,4914 | 5,9439 | $2 \cdot 3 \cdot 5 \cdot 7$ | 2,3222 |
| 662,88 | 34966,7 | 44521 | 9393931 | 211 | 14,5258 | 5,9533 | — | 2,3243 |
| 666,02 | 35298,9 | 44944 | 9528128 | 212 | 14,5602 | 5,9627 | $2^2 \cdot 53$ | 2,3263 |
| 669,16 | 35632,7 | 45369 | 9663597 | 213 | 14,5945 | 5,9721 | $3 \cdot 71$ | 2,3284 |
| 672,30 | 35968,1 | 45796 | 9800344 | 214 | 14,6287 | 5,9814 | $2 \cdot 107$ | 2,3304 |
| 675,44 | 36305,0 | 46225 | 9938375 | 215 | 14,6629 | 5,9907 | $5 \cdot 43$ | 2,3324 |
| 678,58 | 36643,5 | 46656 | 10077696 | 216 | 14,6969 | 6,0000 | $2^3 \cdot 3^3$ | 2,3345 |
| 681,73 | 36983,6 | 47089 | 10218313 | 217 | 14,7309 | 6,0092 | $7 \cdot 31$ | 2,3365 |
| 684,87 | 37325,3 | 47524 | 10360232 | 218 | 14,7648 | 6,0185 | $2 \cdot 109$ | 2,3385 |
| 688,01 | 37668,5 | 47961 | 10503459 | 219 | 14,7986 | 6,0277 | $3 \cdot 73$ | 2,3404 |
| 691,15 | 38013,3 | 48400 | 10648000 | 220 | 14,8324 | 6,0368 | $2^2 \cdot 5 \cdot 11$ | 2,3424 |
| 694,29 | 38359,6 | 48841 | 10793861 | 221 | 14,8661 | 6,0459 | $13 \cdot 17$ | 2,3444 |
| 697,43 | 38707,6 | 49284 | 10941048 | 222 | 14,8997 | 6,0550 | $2 \cdot 3 \cdot 37$ | 2,3464 |
| 700,58 | 39057,1 | 49729 | 11089567 | 223 | 14,9332 | 6,0641 | — | 2,3483 |
| 703,72 | 39408,1 | 50176 | 11239424 | 224 | 14,9666 | 6,0732 | $2^5 \cdot 7$ | 2,3503 |
| 706,86 | 39760,8 | 50625 | 11390625 | 225 | 15,0000 | 6,0822 | $3^2 \cdot 5^2$ | 2,3522 |
| 710,00 | 40115,0 | 51076 | 11543176 | 226 | 15,0333 | 6,0912 | $2 \cdot 113$ | 2,3541 |
| 713,14 | 40470,8 | 51529 | 11697083 | 227 | 15,0665 | 6,1002 | — | 2,3560 |
| 716,28 | 40828,1 | 51984 | 11852352 | 228 | 15,0997 | 6,1091 | $2^2 \cdot 3 \cdot 19$ | 2,3579 |
| 719,42 | 41187,1 | 52441 | 12008989 | 229 | 15,1327 | 6,1180 | — | 2,3598 |
| 722,57 | 41547,6 | 52900 | 12167000 | 230 | 15,1658 | 6,1269 | $2 \cdot 5 \cdot 23$ | 2,3617 |
| 725,71 | 41909,6 | 53361 | 12326391 | 231 | 15,1987 | 6,1358 | $3 \cdot 7 \cdot 11$ | 2,3636 |
| 728,85 | 42273,3 | 53824 | 12487168 | 232 | 15,2315 | 6,1446 | $2^2 \cdot 29$ | 2,3655 |
| 731,99 | 42638,5 | 54289 | 12649337 | 233 | 15,2643 | 6,1534 | — | 2,3674 |
| 735,13 | 43005,3 | 54756 | 12812904 | 234 | 15,2971 | 6,1622 | $2 \cdot 3^2 \cdot 13$ | 2,3692 |
| 738,27 | 43373,6 | 55225 | 12977875 | 235 | 15,3297 | 6,1710 | $5 \cdot 47$ | 2,3711 |
| 741,42 | 43743,5 | 55696 | 13144256 | 236 | 15,3623 | 6,1797 | $2^2 \cdot 59$ | 2,3729 |
| 744,56 | 44115,0 | 56169 | 13312053 | 237 | 15,3948 | 6,1885 | $3 \cdot 79$ | 2,3748 |
| 747,70 | 44488,1 | 56644 | 13481272 | 238 | 15,4272 | 6,1972 | $2 \cdot 7 \cdot 17$ | 2,3766 |
| 750,84 | 44862,7 | 57121 | 13651919 | 239 | 15,4596 | 6,2058 | — | 2,3784 |
| 753,98 | 45238,9 | 57600 | 13824000 | 240 | 15,4919 | 6,2145 | $2^4 \cdot 3 \cdot 5$ | 2,3802 |
| 757,12 | 45616,7 | 58081 | 13997521 | 241 | 15,5242 | 6,2231 | — | 2,3820 |
| 760,27 | 45996,1 | 58564 | 14172488 | 242 | 15,5563 | 6,2317 | $2 \cdot 11^2$ | 2,3838 |
| 763,41 | 46377,0 | 59049 | 14348907 | 243 | 15,5885 | 6,2403 | $3^5$ | 2,3856 |
| 766,55 | 46759,5 | 59536 | 14526784 | 244 | 15,6205 | 6,2488 | $2^2 \cdot 61$ | 2,3874 |
| 769,69 | 47143,5 | 60025 | 14706125 | 245 | 15,6525 | 6,2573 | $5 \cdot 7^2$ | 2,3892 |
| 772,83 | 47529,2 | 60516 | 14886936 | 246 | 15,6844 | 6,2658 | $2 \cdot 3 \cdot 41$ | 2,3909 |
| 775,97 | 47916,4 | 61009 | 15069223 | 247 | 15,7162 | 6,2743 | $13 \cdot 19$ | 2,3927 |
| 779,11 | 48305,1 | 61504 | 15252992 | 248 | 15,7480 | 6,2828 | $2^3 \cdot 31$ | 2,3945 |
| 782,26 | 48695,5 | 62001 | 15438249 | 249 | 15,7779 | 6,2912 | $3 \cdot 83$ | 2,3962 |
| 785,40 | 49087,4 | 62500 | 15625000 | 250 | 15,8114 | 6,2996 | $2 \cdot 5^3$ | 2,3979 |

201 ... 250

| $C = \pi \cdot d$ | $A = \frac{\pi \cdot d^2}{4}$ | $A = n^2$ | $V = n^3$ | Number $d$ or $n$ | $\sqrt{n}$ | $\sqrt[3]{n}$ | Factors and primes | lg $n$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 2 | 3 | | $\frac{1}{2}$ | $\frac{1}{3}$ | — | — |
| 788,54 | 49480,9 | 63001 | 15813251 | 251 | 15,8430 | 6,3080 | — | 2,3997 |
| 791,68 | 49875,9 | 63504 | 16003008 | 252 | 15,8745 | 6,3164 | $2^2 \cdot 3^2 \cdot 7$ | 2,4014 |
| 794,82 | 50272,6 | 64009 | 16194277 | 253 | 15,9060 | 6,3247 | $11 \cdot 23$ | 2,4031 |
| 797,96 | 50670,7 | 64516 | 16387064 | 254 | 15,9374 | 6,3330 | $2 \cdot 127$ | 2,4048 |
| 801,11 | 51070,5 | 65025 | 16581375 | 255 | 15,9687 | 6,3413 | $3 \cdot 5 \cdot 17$ | 2,4065 |
| 804,25 | 51471,9 | 65536 | 16777216 | 256 | 16,0000 | 6,3496 | $2^8$ | 2,4082 |
| 807,39 | 51874,8 | 66049 | 16974593 | 257 | 16,0312 | 6,3579 | — | 2,4099 |
| 810,53 | 52279,2 | 66564 | 17173512 | 258 | 16,0624 | 6,3661 | $2 \cdot 3 \cdot 43$ | 2,4116 |
| 813,67 | 52685,3 | 67081 | 17373979 | 259 | 16,0935 | 6,3743 | $7 \cdot 37$ | 2,4133 |
| 816,81 | 53092,9 | 67600 | 17576000 | 260 | 16,1245 | 6,3825 | $2^2 \cdot 5 \cdot 13$ | 2,4150 |
| 819,96 | 53502,1 | 68121 | 17779581 | 261 | 16,1555 | 6,3907 | $3^2 \cdot 29$ | 2,4166 |
| 823,10 | 53912,9 | 68644 | 17984728 | 262 | 16,1864 | 6,3988 | $2 \cdot 131$ | 2,4183 |
| 826,24 | 54325,2 | 69169 | 18191447 | 263 | 16,2173 | 6,4070 | — | 2,4200 |
| 829,38 | 54739,1 | 69696 | 18399744 | 264 | 16,2481 | 6,4151 | $2^3 \cdot 3 \cdot 11$ | 2,4216 |
| 832,52 | 55154,6 | 70225 | 18609625 | 265 | 16,2788 | 6,4232 | $5 \cdot 53$ | 2,4233 |
| 835,66 | 55571,6 | 70756 | 18821096 | 266 | 16,3095 | 6,4312 | $2 \cdot 7 \cdot 19$ | 2,4249 |
| 838,81 | 55990,2 | 71289 | 19034163 | 267 | 16,3401 | 6,4393 | $3 \cdot 89$ | 2,4265 |
| 841,95 | 56410,4 | 71824 | 19248832 | 268 | 16,3707 | 6,4473 | $2^2 \cdot 67$ | 2,4281 |
| 845,09 | 56832,2 | 72361 | 19465109 | 269 | 16,4012 | 6,4553 | — | 2,4298 |
| 848,23 | 57255,5 | 72900 | 19683000 | 270 | 16,4317 | 6,4633 | $2 \cdot 3^3 \cdot 5$ | 2,4314 |
| 851,37 | 57680,4 | 73441 | 19902511 | 271 | 16,4621 | 6,4713 | — | 2,4330 |
| 854,51 | 58106,9 | 73984 | 20123648 | 272 | 16,4924 | 6,4792 | $2^4 \cdot 17$ | 2,4346 |
| 857,65 | 58534,9 | 74529 | 20346417 | 273 | 16,5227 | 6,4872 | $3 \cdot 7 \cdot 13$ | 2,4362 |
| 860,80 | 58964,6 | 75076 | 20570824 | 274 | 16,5529 | 6,4951 | $2 \cdot 137$ | 2,4378 |
| 863,94 | 59395,7 | 75625 | 20796875 | 275 | 16,5831 | 6,5030 | $5^2 \cdot 11$ | 2,4393 |
| 867,08 | 59828,5 | 76176 | 21024576 | 276 | 16,6132 | 6,5108 | $2^2 \cdot 3 \cdot 23$ | 2,4409 |
| 870,22 | 60262,8 | 76729 | 21253933 | 277 | 16,6433 | 6,5187 | — | 2,4425 |
| 873,36 | 60698,7 | 77284 | 21484952 | 278 | 16,6733 | 6,5265 | $2 \cdot 139$ | 2,4440 |
| 876,50 | 61136,2 | 77841 | 21717639 | 279 | 16,7033 | 6,5343 | $3^2 \cdot 31$ | 2,4456 |
| 879,65 | 61575,2 | 78400 | 21952000 | 280 | 16,7332 | 6,5421 | $2^3 \cdot 5 \cdot 7$ | 2,4472 |
| 882,79 | 62015,8 | 78961 | 22188041 | 281 | 16,7631 | 6,5499 | — | 2,4487 |
| 885,93 | 62458,0 | 79524 | 22425768 | 282 | 16,7929 | 6,5577 | $2 \cdot 3 \cdot 47$ | 2,4503 |
| 889,07 | 62901,8 | 80089 | 22665187 | 283 | 16,8226 | 6,5654 | — | 2,4518 |
| 892,21 | 63347,1 | 80656 | 22906304 | 284 | 16,8523 | 6,5731 | $2^2 \cdot 71$ | 2,4533 |
| 895,35 | 63794,0 | 81225 | 23149125 | 285 | 16,8819 | 6,5808 | $3 \cdot 5 \cdot 19$ | 2,4548 |
| 898,50 | 64242,4 | 81796 | 23393656 | 286 | 16,9115 | 6,5885 | $2 \cdot 11 \cdot 13$ | 2,4564 |
| 901,64 | 64692,5 | 82369 | 23639903 | 287 | 16,9411 | 6,5962 | $7 \cdot 41$ | 2,4579 |
| 904,78 | 65144,1 | 82944 | 23887872 | 288 | 16,9706 | 6,6039 | $2^5 \cdot 3^2$ | 2,4594 |
| 907,92 | 65597,2 | 83521 | 24137569 | 289 | 17,0000 | 6,6115 | $17^2$ | 2,4609 |
| 911,06 | 66052,0 | 84100 | 24389000 | 290 | 17,0294 | 6,6191 | $2 \cdot 5 \cdot 29$ | 2,4624 |
| 914,20 | 66508,3 | 84681 | 24642171 | 291 | 17,0587 | 6,6267 | $3 \cdot 97$ | 2,4639 |
| 917,35 | 66966,2 | 85264 | 24897088 | 292 | 17,0880 | 6,6343 | $2^2 \cdot 73$ | 2,4654 |
| 920,49 | 67425,6 | 85849 | 25153757 | 293 | 17,1172 | 6,6419 | — | 2,4669 |
| 923,63 | 67886,7 | 86436 | 25412184 | 294 | 17,1464 | 6,6494 | $2 \cdot 3 \cdot 7^2$ | 2,4684 |
| 926,77 | 68349,3 | 87025 | 25672375 | 295 | 17,1756 | 6,6569 | $5 \cdot 59$ | 2,4698 |
| 929,91 | 68813,4 | 87616 | 25934336 | 296 | 17,2047 | 6,6644 | $2^3 \cdot 37$ | 2,4713 |
| 933,05 | 69279,2 | 88209 | 26198073 | 297 | 17,2337 | 6,6719 | $3^3 \cdot 11$ | 2,4728 |
| 936,19 | 69746,5 | 88804 | 26463592 | 298 | 17,2627 | 6,6794 | $2 \cdot 149$ | 2,4742 |
| 939,34 | 70215,4 | 89401 | 26730899 | 299 | 17,2916 | 6,6869 | $13 \cdot 23$ | 2,4757 |
| 942,48 | 70685,8 | 90000 | 27000000 | 300 | 17,3205 | 6,6943 | $2^2 \cdot 3 \cdot 5^3$ | 2,4771 |

251 ... 300

| $C = \pi \cdot d$ | $A = \frac{\pi \cdot d^2}{4}$ | $A = n^2$ | $V = n^3$ | Number $d$ or $n$ | $\sqrt{n}$ | $\sqrt[3]{n}$ | Factors and primes | lg $n$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 2 | 3 | | $\frac{1}{2}$ | $\frac{1}{3}$ | — | — |
| 945,62 | 71157,9 | 90601 | 27270901 | 301 | 17,3494 | 6,7018 | 7 · 43 | 2,4786 |
| 948,76 | 71631,5 | 91204 | 27543608 | 302 | 17,3781 | 6,7092 | 2 · 151 | 2,4800 |
| 951,90 | 72106,6 | 91809 | 27818127 | 303 | 17,4069 | 6,7166 | 3 · 101 | 2,4814 |
| 955,04 | 72583,4 | 92416 | 28094464 | 304 | 17,4356 | 6,7240 | $2^4 \cdot 19$ | 2,4829 |
| 958,19 | 73061,7 | 93025 | 28372625 | 305 | 17,4642 | 6,7313 | 5 · 61 | 2,4843 |
| 961,33 | 73541,5 | 93636 | 28652616 | 306 | 17,4929 | 6,7387 | $2 \cdot 3^2 \cdot 17$ | 2,4857 |
| 964,47 | 74023,0 | 94249 | 28934443 | 307 | 17,5214 | 6,7460 | — | 2,4871 |
| 967,61 | 74506,0 | 94864 | 29218112 | 308 | 17,5499 | 6,7533 | $2^2 \cdot 7 \cdot 11$ | 2,4886 |
| 970,75 | 74990,6 | 95481 | 29503629 | 309 | 17,5784 | 6,7606 | 3 · 103 | 2,4900 |
| 973,89 | 75476,8 | 96100 | 29791000 | 310 | 17,6068 | 6,7679 | 2 · 5 · 31 | 2,4914 |
| 977,04 | 75964,5 | 96721 | 30080231 | 311 | 17,6352 | 6,7752 | — | 2,4928 |
| 980,18 | 76453,8 | 97344 | 30371328 | 312 | 17,6635 | 6,7824 | $2^2 \cdot 3 \cdot 13$ | 2,4942 |
| 983,32 | 76944,7 | 97969 | 30664297 | 313 | 17,6918 | 6,7897 | — | 2,4955 |
| 986,46 | 77437,1 | 98596 | 30959144 | 314 | 17,7200 | 6,7969 | 2 · 157 | 2,4969 |
| 989,60 | 77931,1 | 99225 | 31255875 | 315 | 17,7482 | 6,8041 | $3^2 \cdot 5 \cdot 7$ | 2,4983 |
| 992,74 | 78426,7 | 99856 | 31554496 | 316 | 17,7764 | 6,8113 | $2^2 \cdot 79$ | 2,4997 |
| 995,88 | 78923,9 | 100489 | 31855013 | 317 | 17,8045 | 6,8185 | — | 2,5011 |
| 999,03 | 79422,6 | 101124 | 32157432 | 318 | 17,8326 | 6,8256 | 2 · 3 · 53 | 2,5024 |
| 1002,2 | 79922,9 | 101761 | 32461759 | 319 | 17,8606 | 6,8328 | 11 · 29 | 2,5038 |
| 1005,3 | 80424,8 | 102400 | 32768000 | 320 | 17,8885 | 6,8399 | $2^8 \cdot 5$ | 2,5052 |
| 1008,5 | 80928,2 | 103041 | 33076161 | 321 | 17,9165 | 6,8470 | 3 · 107 | 2,5065 |
| 1011,6 | 81433,2 | 103684 | 33386248 | 322 | 17,9444 | 6,8541 | 2 · 7 · 23 | 2,5079 |
| 1014,7 | 81939,8 | 104329 | 33698267 | 323 | 17,9722 | 6,8612 | 17 · 19 | 2,5092 |
| 1017,9 | 82448,0 | 104976 | 34012224 | 324 | 18,0000 | 6,8683 | $2^2 \cdot 3^4$ | 2,5106 |
| 1021,0 | 82957,7 | 105625 | 34328125 | 325 | 18,0278 | 6,8753 | $5^2 \cdot 13$ | 2,5119 |
| 1024,2 | 83469,0 | 106276 | 34645976 | 326 | 18,0555 | 6,8824 | 2 · 163 | 2,5132 |
| 1027,3 | 83981,8 | 106929 | 34965783 | 327 | 18,0831 | 6,8894 | 3 · 109 | 2,5146 |
| 1030,4 | 84496,3 | 107584 | 35287552 | 328 | 18,1108 | 6,8964 | $2^3 \cdot 41$ | 2,5159 |
| 1033,6 | 85012,3 | 108241 | 35611289 | 329 | 18,1384 | 6,9034 | 7 · 47 | 2,5172 |
| 1036,7 | 85529,9 | 108900 | 35937000 | 330 | 18,1659 | 6,9104 | $2 \cdot 3 \cdot 5 \cdot 11$ | 2,5185 |
| 1039,9 | 86049,0 | 109561 | 36264691 | 331 | 18,1934 | 6,9174 | — | 2,5198 |
| 1043,0 | 86569,7 | 110224 | 36594368 | 332 | 18,2209 | 6,9244 | $2^2 \cdot 83$ | 2,5211 |
| 1046,2 | 87092,0 | 110889 | 36926037 | 333 | 18,2483 | 6,9313 | $3^2 \cdot 37$ | 2,5224 |
| 1049,3 | 87615,9 | 111556 | 37259704 | 334 | 18,2757 | 6,9382 | 2 · 167 | 2,5238 |
| 1052,4 | 88141,3 | 112225 | 37595375 | 335 | 18,3030 | 6,9451 | 5 · 67 | 2,5250 |
| 1055,6 | 88668,3 | 112896 | 37933056 | 336 | 18,3303 | 6,9521 | $2^4 \cdot 3 \cdot 7$ | 2,5263 |
| 1058,7 | 89196,9 | 113569 | 38272753 | 337 | 18,3576 | 6,9589 | — | 2,5276 |
| 1061,9 | 89727,0 | 114244 | 38614472 | 338 | 18,3848 | 6,9658 | $2 \cdot 13^2$ | 2,5289 |
| 1065,0 | 90258,7 | 114921 | 38958219 | 339 | 18,4120 | 6,9727 | 3 · 113 | 2,5302 |
| 1068,1 | 90792,0 | 115600 | 39304000 | 340 | 18,4391 | 6,9795 | $2^2 \cdot 5 \cdot 17$ | 2,5315 |
| 1071,3 | 91326,9 | 116281 | 39651821 | 341 | 18,4662 | 6,9864 | 11 · 31 | 2,5328 |
| 1074,4 | 91863,3 | 116964 | 40001688 | 342 | 18,4932 | 6,9932 | $2 \cdot 3^2 \cdot 19$ | 2,5340 |
| 1077,6 | 92401,3 | 117649 | 40353607 | 343 | 18,5203 | 7,0000 | $7^3$ | 2,5353 |
| 1080,7 | 92940,9 | 118336 | 40707584 | 344 | 18,5472 | 7,0068 | $2^3 \cdot 43$ | 2,5366 |
| 1083,8 | 93482,0 | 119025 | 41063625 | 345 | 18,5742 | 7,0136 | $3 \cdot 5 \cdot 23$ | 2,5378 |
| 1087,0 | 94024,7 | 119716 | 41421736 | 346 | 18,6011 | 7,0203 | 2 · 173 | 2,5391 |
| 1090,1 | 94569,0 | 120409 | 41781923 | 347 | 18,6279 | 7,0271 | — | 2,5403 |
| 1093,3 | 95114,9 | 121104 | 42144192 | 348 | 18,6548 | 7,0338 | $2^2 \cdot 3 \cdot 29$ | 2,5416 |
| 1096,4 | 95662,3 | 121801 | 42508549 | 349 | 18,6815 | 7,0406 | — | 2,5428 |
| 1099,6 | 96211,3 | 122500 | 42875000 | 350 | 18,7083 | 7,0473 | $2 \cdot 5^2 \cdot 7$ | 2,5441 |



| $C = \pi \cdot d$ | $A = \frac{\pi \cdot d^2}{4}$ | $A = n^2$ | $V = n^3$ | Number $d$ or $n$ | $\sqrt{n}$ | $\sqrt[3]{n}$ | Factors and primes | lg $n$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 2 | 3 | | $\frac{1}{2}$ | $\frac{1}{3}$ | — | — |
| 1102,7 | 96761,8 | 123201 | 43243551 | 351 | 18,7350 | 7,0540 | $3^3 \cdot 13$ | 2,5453 |
| 1105,8 | 97314,0 | 123904 | 43614208 | 352 | 18,7617 | 7,0607 | $2^5 \cdot 11$ | 2,5465 |
| 1109,0 | 97867,7 | 124609 | 43986977 | 353 | 18,7883 | 7,0674 | — | 2,5478 |
| 1112,1 | 98423,0 | 125316 | 44361864 | 354 | 18,8149 | 7,0740 | $2 \cdot 3 \cdot 59$ | 2,5490 |
| 1115,3 | 98979,8 | 126025 | 44738875 | 355 | 18,8414 | 7,0807 | $5 \cdot 71$ | 2,5502 |
| 1118,4 | 99538,2 | 126736 | 45118016 | 356 | 18,8680 | 7,0873 | $2^2 \cdot 89$ | 2,5515 |
| 1121,5 | 100098 | 127449 | 45499293 | 357 | 18,8944 | 7,0940 | $3 \cdot 7 \cdot 17$ | 2,5527 |
| 1124,7 | 100660 | 128164 | 45882712 | 358 | 18,9209 | 7,1006 | $2 \cdot 179$ | 2,5539 |
| 1127,8 | 101223 | 128881 | 46268279 | 359 | 18,9473 | 7,1072 | — | 2,5551 |
| 1131,0 | 101788 | 129600 | 46656000 | 360 | 18,9737 | 7,1138 | $2^3 \cdot 3^2 \cdot 5$ | 2,5563 |
| 1134,1 | 102354 | 130321 | 47045881 | 361 | 19,0000 | 7,1204 | $19^2$ | 2,5575 |
| 1137,3 | 102922 | 131044 | 47437928 | 362 | 19,0263 | 7,1269 | $2 \cdot 181$ | 2,5587 |
| 1140,4 | 103491 | 131769 | 47832147 | 363 | 19,0526 | 7,1335 | $3 \cdot 11^2$ | 2,5599 |
| 1143,5 | 104062 | 132496 | 48228544 | 364 | 19,0788 | 7,1400 | $2^2 \cdot 7 \cdot 13$ | 2,5611 |
| 1146,7 | 104635 | 133225 | 48627125 | 365 | 19,1050 | 7,1466 | $5 \cdot 73$ | 2,5623 |
| 1149,8 | 105209 | 133956 | 49027896 | 366 | 19,1311 | 7,1531 | $2 \cdot 3 \cdot 61$ | 2,5635 |
| 1153,0 | 105785 | 134689 | 49430863 | 367 | 19,1572 | 7,1596 | — | 2,5647 |
| 1156,1 | 106362 | 135424 | 49836032 | 368 | 19,1833 | 7,1661 | $2^4 \cdot 23$ | 2,5659 |
| 1159,2 | 106941 | 136161 | 50243409 | 369 | 19,2094 | 7,1726 | $3^2 \cdot 41$ | 2,5670 |
| 1162,4 | 107521 | 136900 | 50653000 | 370 | 19,2354 | 7,1791 | $2 \cdot 5 \cdot 37$ | 2,5682 |
| 1165,5 | 108103 | 137641 | 51064811 | 371 | 19,2614 | 7,1855 | $7 \cdot 53$ | 2,5694 |
| 1168,7 | 108687 | 138384 | 51478848 | 372 | 19,2873 | 7,1920 | $2^2 \cdot 3 \cdot 31$ | 2,5705 |
| 1171,8 | 109272 | 139129 | 51895117 | 373 | 19,3132 | 7,1984 | — | 2,5717 |
| 1175,0 | 109858 | 139876 | 52313624 | 374 | 19,3391 | 7,2048 | $2 \cdot 11 \cdot 17$ | 2,5729 |
| 1178,1 | 110447 | 140625 | 52734375 | 375 | 19,3649 | 7,2112 | $3 \cdot 5^3$ | 2,5740 |
| 1181,2 | 111036 | 141376 | 53157376 | 376 | 19,3907 | 7,2177 | $2^3 \cdot 47$ | 2,5752 |
| 1184,4 | 111628 | 142129 | 53582633 | 377 | 19,4165 | 7,2240 | $13 \cdot 29$ | 2,5763 |
| 1187,5 | 112221 | 142884 | 54010152 | 378 | 19,4422 | 7,2304 | $2 \cdot 3^3 \cdot 7$ | 2,5775 |
| 1190,7 | 112815 | 143641 | 54439939 | 379 | 19,4679 | 7,2368 | — | 2,5786 |
| 1193,8 | 113411 | 144400 | 54872000 | 380 | 19,4936 | 7,2432 | $2^2 \cdot 5 \cdot 19$ | 2,5798 |
| 1196,9 | 114009 | 145161 | 55306341 | 381 | 19,5192 | 7,2495 | $3 \cdot 127$ | 2,5809 |
| 1200,1 | 114608 | 145924 | 55742968 | 382 | 19,5448 | 7,2558 | $2 \cdot 191$ | 2,5821 |
| 1203,2 | 115209 | 146689 | 56181887 | 383 | 19,5704 | 7,2622 | — | 2,5832 |
| 1206,4 | 115812 | 147456 | 56623104 | 384 | 19,5959 | 7,2685 | $2^7 \cdot 3$ | 2,5843 |
| 1209,5 | 116416 | 148225 | 57066625 | 385 | 19,6214 | 7,2748 | $5 \cdot 7 \cdot 11$ | 2,5855 |
| 1212,7 | 117021 | 148996 | 57512456 | 386 | 19,6469 | 7,2811 | $2 \cdot 193$ | 2,5866 |
| 1215,8 | 117628 | 149769 | 57960603 | 387 | 19,6723 | 7,2874 | $3^2 \cdot 43$ | 2,5877 |
| 1218,9 | 118237 | 150544 | 58411072 | 388 | 19,6977 | 7,2936 | $2^2 \cdot 97$ | 2,5888 |
| 1222,1 | 118847 | 151321 | 58863869 | 389 | 19,7231 | 7,2999 | — | 2,5900 |
| 1225,2 | 119459 | 152100 | 59319000 | 390 | 19,7484 | 7,3061 | $2 \cdot 3 \cdot 5 \cdot 13$ | 2,5911 |
| 1228,4 | 120072 | 152881 | 59776471 | 391 | 19,7737 | 7,3124 | $17 \cdot 23$ | 2,5922 |
| 1231,5 | 120687 | 153664 | 60236288 | 392 | 19,7990 | 7,3186 | $2^3 \cdot 7^2$ | 2,5933 |
| 1234,6 | 121304 | 154449 | 60698457 | 393 | 19,8242 | 7,3248 | $3 \cdot 131$ | 2,5944 |
| 1237,8 | 121922 | 155236 | 61162984 | 394 | 19,8494 | 7,3310 | $2 \cdot 197$ | 2,5955 |
| 1240,9 | 122542 | 156025 | 61629875 | 395 | 19,8746 | 7,3372 | $5 \cdot 79$ | 2,5966 |
| 1244,1 | 123163 | 156816 | 62099136 | 396 | 19,8997 | 7,3434 | $2^2 \cdot 3^2 \cdot 11$ | 2,5977 |
| 1247,2 | 123786 | 157609 | 62570773 | 397 | 19,9249 | 7,3496 | — | 2,5988 |
| 1250,4 | 124410 | 158404 | 63044792 | 398 | 19,9499 | 7,3558 | $2 \cdot 199$ | 2,5999 |
| 1253,5 | 125036 | 159201 | 63521199 | 399 | 19,9750 | 7,3619 | $3 \cdot 7 \cdot 19$ | 2,6010 |
| 1256,6 | 125664 | 160000 | 64000000 | 400 | 20,0000 | 7,3681 | $2^4 \cdot 5^2$ | 2,6021 |

351 ... 400

| $C = \pi \cdot d$ | $A = \frac{\pi \cdot d^2}{4}$ | $A = n^2$ | $V = n^3$ | Number $d$ or $n$ | $\sqrt{n}$ | $\sqrt[3]{n}$ | Factors and primes | $\lg n$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 2 | 3 | | $\frac{1}{2}$ | $\frac{1}{3}$ | — | — |
| 1259,8 | 126293 | 160801 | 64481201 | 401 | 20,0250 | 7,3742 | — | 2,6031 |
| 1262,9 | 126923 | 161604 | 64964808 | 402 | 20,0499 | 7,3803 | $2 \cdot 3 \cdot 67$ | 2,6042 |
| 1266,1 | 127556 | 162409 | 65450827 | 403 | 20,0749 | 7,3864 | $13 \cdot 31$ | 2,6053 |
| 1269,2 | 128190 | 163216 | 65939264 | 404 | 20,0998 | 7,3925 | $2^2 \cdot 101$ | 2,6064 |
| 1272,3 | 128825 | 164025 | 66430125 | 405 | 20,1246 | 7,3986 | $3^4 \cdot 5$ | 2,6075 |
| 1275,5 | 129462 | 164836 | 66923416 | 406 | 20,1494 | 7,4047 | $2 \cdot 7 \cdot 29$ | 2,6085 |
| 1278,6 | 130100 | 165649 | 67419143 | 407 | 20,1742 | 7,4108 | $11 \cdot 37$ | 2,6096 |
| 1281,8 | 130741 | 166464 | 67917312 | 408 | 20,1990 | 7,4169 | $2^3 \cdot 3 \cdot 17$ | 2,6107 |
| 1284,9 | 131382 | 167281 | 68417929 | 409 | 20,2237 | 7,4229 | — | 2,6117 |
| 1288,1 | 132025 | 168100 | 68921000 | 410 | 20,2485 | 7,4290 | $2 \cdot 5 \cdot 41$ | 2,6128 |
| 1291,2 | 132670 | 168921 | 69426531 | 411 | 20,2731 | 7,4350 | $3 \cdot 137$ | 2,6138 |
| 1294,3 | 133317 | 169744 | 69934528 | 412 | 20,2978 | 7,4410 | $2^2 \cdot 103$ | 2,6149 |
| 1297,5 | 133965 | 170569 | 70444997 | 413 | 20,3224 | 7,4470 | $7 \cdot 59$ | 2,6160 |
| 1300,6 | 134614 | 171396 | 70957944 | 414 | 20,3470 | 7,4530 | $2 \cdot 3^2 \cdot 23$ | 2,6170 |
| 1303,8 | 135265 | 172225 | 71473375 | 415 | 20,3715 | 7,4590 | $5 \cdot 83$ | 2,6181 |
| 1306,9 | 135918 | 173056 | 71991296 | 416 | 20,3961 | 7,4650 | $2^5 \cdot 13$ | 2,6191 |
| 1310,0 | 136572 | 173889 | 72511713 | 417 | 20,4206 | 7,4710 | $3 \cdot 139$ | 2,6201 |
| 1313,2 | 137228 | 174724 | 73034632 | 418 | 20,4450 | 7,4770 | $2 \cdot 11 \cdot 19$ | 2,6212 |
| 1316,3 | 137885 | 175561 | 73560059 | 419 | 20,4695 | 7,4829 | — | 2,6222 |
| 1319,5 | 138544 | 176400 | 74088000 | 420 | 20,4939 | 7,4889 | $2^2 \cdot 3 \cdot 5 \cdot 7$ | 2,6233 |
| 1322,6 | 139205 | 177241 | 74618461 | 421 | 20,5183 | 7,4948 | — | 2,6243 |
| 1325,8 | 139867 | 178084 | 75151448 | 422 | 20,5426 | 7,5007 | $2 \cdot 211$ | 2,6253 |
| 1328,9 | 140531 | 178929 | 75686967 | 423 | 20,5670 | 7,5067 | $3^2 \cdot 47$ | 2,6263 |
| 1332,0 | 141196 | 179776 | 76225024 | 424 | 20,5913 | 7,5126 | $2^3 \cdot 53$ | 2,6274 |
| 1335,2 | 141863 | 180625 | 76765625 | 425 | 20,6155 | 7,5185 | $5^2 \cdot 17$ | 2,6284 |
| 1338,3 | 142531 | 181476 | 77308776 | 426 | 20,6398 | 7,5244 | $2 \cdot 3 \cdot 71$ | 2,6294 |
| 1341,5 | 143201 | 182329 | 77854483 | 427 | 20,6640 | 7,5302 | $7 \cdot 61$ | 2,6304 |
| 1344,6 | 143872 | 183184 | 78402752 | 428 | 20,6882 | 7,5361 | $2^2 \cdot 107$ | 2,6314 |
| 1347,7 | 144545 | 184041 | 78953589 | 429 | 20,7123 | 7,5420 | $3 \cdot 11 \cdot 13$ | 2,6325 |
| 1350,9 | 145220 | 184900 | 79507000 | 430 | 20,7364 | 7,5478 | $2 \cdot 5 \cdot 43$ | 2,6335 |
| 1354,0 | 145896 | 185761 | 80062991 | 431 | 20,7605 | 7,5537 | — | 2,6345 |
| 1357,2 | 146574 | 186624 | 80621568 | 432 | 20,7846 | 7,5595 | $2^4 \cdot 3^3$ | 2,6355 |
| 1360,3 | 147254 | 187489 | 81182737 | 433 | 20,8087 | 7,5654 | — | 2,6365 |
| 1363,5 | 147934 | 188356 | 81746504 | 434 | 20,8327 | 7,5712 | $2 \cdot 7 \cdot 31$ | 2,6375 |
| 1366,6 | 148617 | 189225 | 82312875 | 435 | 20,8567 | 7,5770 | $3 \cdot 5 \cdot 29$ | 2,6385 |
| 1369,7 | 149301 | 190096 | 82881856 | 436 | 20,8806 | 7,5828 | $2^2 \cdot 109$ | 2,6395 |
| 1372,9 | 149987 | 190969 | 83453453 | 437 | 20,9045 | 7,5886 | $19 \cdot 23$ | 2,6405 |
| 1376,0 | 150674 | 191844 | 84027672 | 438 | 20,9284 | 7,5944 | $2 \cdot 3 \cdot 73$ | 2,6415 |
| 1379,2 | 151363 | 192721 | 84604519 | 439 | 20,9523 | 7,6001 | — | 2,6425 |
| 1382,3 | 152053 | 193600 | 85184000 | 440 | 20,9762 | 7,6059 | $2^3 \cdot 5 \cdot 11$ | 2,6435 |
| 1385,4 | 152745 | 194481 | 85766121 | 441 | 21,0000 | 7,6117 | $3^2 \cdot 7^2$ | 2,6444 |
| 1388,6 | 153439 | 195364 | 86350888 | 442 | 21,0238 | 7,6174 | $2 \cdot 13 \cdot 17$ | 2,6454 |
| 1391,7 | 154134 | 196249 | 86938307 | 443 | 21,0476 | 7,6232 | — | 2,6464 |
| 1394,9 | 154830 | 197136 | 87528384 | 444 | 21,0713 | 7,6289 | $2^2 \cdot 3 \cdot 37$ | 2,6474 |
| 1398,0 | 155528 | 198025 | 88121125 | 445 | 21,0950 | 7,6346 | $5 \cdot 89$ | 2,6484 |
| 1401,2 | 156228 | 198916 | 88716536 | 446 | 21,1187 | 7,6403 | $2 \cdot 223$ | 2,6493 |
| 1404,3 | 156930 | 199809 | 89314623 | 447 | 21,1424 | 7,6460 | $3 \cdot 149$ | 2,6503 |
| 1407,4 | 157633 | 200704 | 89915392 | 448 | 21,1660 | 7,6517 | $2^6 \cdot 7$ | 2,6513 |
| 1410,6 | 158337 | 201601 | 90518849 | 449 | 21,1896 | 7,6574 | — | 2,6523 |
| 1413,7 | 159043 | 202500 | 91125000 | 450 | 21,2132 | 7,6631 | $2 \cdot 3^2 \cdot 5^2$ | 2,6532 |

401 ... 450

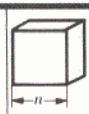
451 ... 500

| $C = \pi \cdot d$ | $A = \frac{\pi \cdot d^2}{4}$ | $A = n^2$ | $V = n^3$ | Number $d$ or $n$ | $\sqrt{n}$ | $\sqrt[3]{n}$ | Factors and primes | lg $n$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 2 | 3 | | $\frac{1}{2}$ | $\frac{1}{3}$ | — | — |
| 1416,9 | 159751 | 203401 | 91733851 | 451 | 21,2368 | 7,6688 | $11 \cdot 41$ | 2,6542 |
| 1420,0 | 160460 | 204304 | 92345408 | 452 | 21,2603 | 7,6744 | $2^2 \cdot 113$ | 2,6551 |
| 1423,1 | 161171 | 205209 | 92959677 | 453 | 21,2838 | 7,6801 | $3 \cdot 151$ | 2,6561 |
| 1426,3 | 161883 | 206116 | 93576664 | 454 | 21,3073 | 7,6857 | $2 \cdot 227$ | 2,6571 |
| 1429,4 | 162597 | 207025 | 94196375 | 455 | 21,3307 | 7,6914 | $5 \cdot 7 \cdot 13$ | 2,6580 |
| 1432,6 | 163313 | 207936 | 94818816 | 456 | 21,3542 | 7,6970 | $2^3 \cdot 3 \cdot 19$ | 2,6590 |
| 1435,7 | 164030 | 208849 | 95443993 | 457 | 21,3776 | 7,7026 | — | 2,6599 |
| 1438,8 | 164748 | 209764 | 96071912 | 458 | 21,4009 | 7,7082 | $2 \cdot 229$ | 2,6609 |
| 1442,0 | 165468 | 210681 | 96702579 | 459 | 21,4243 | 7,7138 | $3^3 \cdot 17$ | 2,6618 |
| 1445,1 | 166190 | 211600 | 97336000 | 460 | 21,4476 | 7,7194 | $2^2 \cdot 5 \cdot 23$ | 2,6628 |
| 1448,3 | 166914 | 212521 | 97972181 | 461 | 21,4709 | 7,7250 | — | 2,6637 |
| 1451,4 | 167639 | 213444 | 98611128 | 462 | 21,4942 | 7,7306 | $2 \cdot 3 \cdot 7 \cdot 11$ | 2,6646 |
| 1454,6 | 168365 | 214369 | 99252847 | 463 | 21,5174 | 7,7362 | — | 2,6656 |
| 1457,7 | 169093 | 215296 | 99897344 | 464 | 21,5407 | 7,7418 | $2^4 \cdot 29$ | 2,6665 |
| 1460,8 | 169823 | 216225 | 100544625 | 465 | 21,5639 | 7,7473 | $3 \cdot 5 \cdot 31$ | 2,6675 |
| 1464,0 | 170554 | 217156 | 101194696 | 466 | 21,5870 | 7,7529 | $2 \cdot 233$ | 2,6684 |
| 1467,1 | 171287 | 218089 | 101847563 | 467 | 21,6102 | 7,7584 | — | 2,6693 |
| 1470,3 | 172021 | 219024 | 102503232 | 468 | 21,6333 | 7,7639 | $2^2 \cdot 3^2 \cdot 13$ | 2,6703 |
| 1473,4 | 172757 | 219961 | 103161709 | 469 | 21,6564 | 7,7695 | $7 \cdot 67$ | 2,6712 |
| 1476,5 | 173494 | 220900 | 103823000 | 470 | 21,6795 | 7,7750 | $2 \cdot 5 \cdot 47$ | 2,6721 |
| 1479,7 | 174234 | 221841 | 104487111 | 471 | 21,7025 | 7,7805 | $3 \cdot 157$ | 2,6730 |
| 1482,8 | 174974 | 222784 | 105154048 | 472 | 21,7256 | 7,7860 | $2^3 \cdot 59$ | 2,6739 |
| 1486,0 | 175716 | 223729 | 105823817 | 473 | 21,7486 | 7,7915 | $11 \cdot 43$ | 2,6749 |
| 1489,1 | 176460 | 224676 | 106496424 | 474 | 21,7715 | 7,7970 | $2 \cdot 3 \cdot 79$ | 2,6758 |
| 1492,3 | 177205 | 225625 | 107171875 | 475 | 21,7945 | 7,8025 | $5^2 \cdot 19$ | 2,6767 |
| 1495,4 | 177952 | 226576 | 107850176 | 476 | 21,8174 | 7,8079 | $2^2 \cdot 7 \cdot 17$ | 2,6776 |
| 1498,5 | 178701 | 227529 | 108531333 | 477 | 21,8403 | 7,8134 | $3^2 \cdot 53$ | 2,6785 |
| 1501,7 | 179451 | 228484 | 109215352 | 478 | 21,8632 | 7,8188 | $2 \cdot 239$ | 2,6794 |
| 1504,8 | 180203 | 229441 | 109902239 | 479 | 21,8861 | 7,8243 | — | 2,6803 |
| 1508,0 | 180956 | 230400 | 110592000 | 480 | 21,9089 | 7,8297 | $2^5 \cdot 3 \cdot 5$ | 2,6812 |
| 1511,1 | 181711 | 231361 | 111284641 | 481 | 21,9317 | 7,8352 | $13 \cdot 37$ | 2,6822 |
| 1514,2 | 182467 | 232324 | 111980168 | 482 | 21,9545 | 7,8406 | $2 \cdot 241$ | 2,6831 |
| 1517,4 | 183225 | 233289 | 112678587 | 483 | 21,9773 | 7,8460 | $3 \cdot 7 \cdot 23$ | 2,6840 |
| 1520,5 | 183984 | 234256 | 113379904 | 484 | 22,0000 | 7,8514 | $2^2 \cdot 11^2$ | 2,6849 |
| 1523,7 | 184745 | 235225 | 114084125 | 485 | 22,0227 | 7,8568 | $5 \cdot 97$ | 2,6857 |
| 1526,8 | 185508 | 236196 | 114791256 | 486 | 22,0454 | 7,8622 | $2 \cdot 3^5$ | 2,6866 |
| 1530,0 | 186272 | 237169 | 115501303 | 487 | 22,0681 | 7,8676 | — | 2,6875 |
| 1533,1 | 187038 | 238144 | 116214272 | 488 | 22,0907 | 7,8730 | $2^3 \cdot 61$ | 2,6884 |
| 1536,2 | 187805 | 239121 | 116930169 | 489 | 22,1133 | 7,8784 | $3 \cdot 163$ | 2,6893 |
| 1539,4 | 188574 | 240100 | 117649000 | 490 | 22,1359 | 7,8837 | $2 \cdot 5 \cdot 7^2$ | 2,6902 |
| 1542,5 | 189345 | 241081 | 118370771 | 491 | 22,1585 | 7,8891 | — | 2,6911 |
| 1545,7 | 190117 | 242064 | 119095488 | 492 | 22,1811 | 7,8944 | $2^2 \cdot 3 \cdot 41$ | 2,6920 |
| 1548,8 | 190890 | 243049 | 119823157 | 493 | 22,2036 | 7,8998 | $17 \cdot 29$ | 2,6929 |
| 1551,9 | 191665 | 244036 | 120553784 | 494 | 22,2261 | 7,9051 | $2 \cdot 13 \cdot 19$ | 2,6937 |
| 1555,1 | 192442 | 245025 | 121287375 | 495 | 22,2486 | 7,9105 | $3^3 \cdot 5 \cdot 11$ | 2,6946 |
| 1558,2 | 193221 | 246016 | 122023936 | 496 | 22,2711 | 7,9158 | $2^4 \cdot 31$ | 2,6955 |
| 1561,4 | 194000 | 247009 | 122763473 | 497 | 22,2935 | 7,9211 | $7 \cdot 71$ | 2,6964 |
| 1564,5 | 194782 | 248004 | 123505992 | 498 | 22,3159 | 7,9264 | $2 \cdot 3 \cdot 83$ | 2,6972 |
| 1567,7 | 195565 | 249001 | 124251499 | 499 | 22,3383 | 7,9317 | — | 2,6981 |
| 1570,8 | 196350 | 250000 | 125000000 | 500 | 22,3607 | 7,9370 | $2^2 \cdot 5^3$ | 2,6990 |

| $C = \pi \cdot d$ | $A = \frac{\pi \cdot d^2}{4}$ | $A = n^2$ | $V = n^3$ | Number $d$ or $n$ | $\sqrt{n}$ | $\sqrt[3]{n}$ | Factors and primes | lg $n$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 2 | 3 | | $\frac{1}{2}$ | $\frac{1}{3}$ | — | — |
| 1573,9 | 197136 | 251001 | 125751501 | 501 | 22,3830 | 7,9423 | $3 \cdot 167$ | 2,6998 |
| 1577,1 | 197923 | 252004 | 126506008 | 502 | 22,4054 | 7,9476 | $2 \cdot 251$ | 2,7007 |
| 1580,2 | 198713 | 253009 | 127263527 | 503 | 22,4277 | 7,9528 | — | 2,7016 |
| 1583,4 | 199504 | 254016 | 128024064 | 504 | 22,4499 | 7,9581 | $2^3 \cdot 3^2 \cdot 7$ | 2,7024 |
| 1586,5 | 200296 | 255025 | 128787625 | 505 | 22,4722 | 7,9634 | $5 \cdot 101$ | 2,7033 |
| 1589,6 | 201090 | 256036 | 129554216 | 506 | 22,4944 | 7,9686 | $2 \cdot 11 \cdot 23$ | 2,7042 |
| 1592,8 | 201886 | 257049 | 130323843 | 507 | 22,5167 | 7,9739 | $3 \cdot 13^2$ | 2,7050 |
| 1595,9 | 202683 | 258064 | 131096512 | 508 | 22,5389 | 7,9791 | $2^2 \cdot 127$ | 2,7059 |
| 1599,1 | 203482 | 259081 | 131872229 | 509 | 22,5610 | 7,9843 | — | 2,7067 |
| 1602,2 | 204282 | 260100 | 132651000 | 510 | 22,5832 | 7,9896 | $2 \cdot 3 \cdot 5 \cdot 17$ | 2,7076 |
| 1605,4 | 205084 | 261121 | 133432831 | 511 | 22,6053 | 7,9948 | $7 \cdot 73$ | 2,7084 |
| 1608,5 | 205887 | 262144 | 134217728 | 512 | 22,6274 | 8,0000 | $2^9$ | 2,7093 |
| 1611,6 | 206692 | 263169 | 135005697 | 513 | 22,6495 | 8,0052 | $3^3 \cdot 19$ | 2,7101 |
| 1614,8 | 207499 | 264196 | 135796744 | 514 | 22,6716 | 8,0104 | $2 \cdot 257$ | 2,7110 |
| 1617,9 | 208307 | 265225 | 136590875 | 515 | 22,6936 | 8,0156 | $5 \cdot 103$ | 2,7118 |
| 1621,1 | 209117 | 266256 | 137388096 | 516 | 22,7156 | 8,0208 | $2^2 \cdot 3 \cdot 43$ | 2,7127 |
| 1624,2 | 209928 | 267289 | 138188413 | 517 | 22,7376 | 8,0260 | $11 \cdot 47$ | 2,7135 |
| 1627,3 | 210741 | 268324 | 138991832 | 518 | 22,7596 | 8,0311 | $2 \cdot 7 \cdot 37$ | 2,7143 |
| 1630,5 | 211556 | 269361 | 139798359 | 519 | 22,7816 | 8,0363 | $3 \cdot 173$ | 2,7152 |
| 1633,6 | 212372 | 270400 | 140608000 | 520 | 22,8035 | 8,0415 | $2^3 \cdot 5 \cdot 13$ | 2,7160 |
| 1636,8 | 213189 | 271441 | 141420761 | 521 | 22,8254 | 8,0466 | — | 2,7168 |
| 1639,9 | 214008 | 272484 | 142236648 | 522 | 22,8473 | 8,0517 | $2 \cdot 3^2 \cdot 29$ | 2,7177 |
| 1643,1 | 214829 | 273529 | 143055667 | 523 | 22,8692 | 8,0569 | — | 2,7185 |
| 1646,2 | 215651 | 274576 | 143877824 | 524 | 22,8910 | 8,0620 | $2^2 \cdot 131$ | 2,7193 |
| 1649,3 | 216475 | 275625 | 144703125 | 525 | 22,9129 | 8,0671 | $3 \cdot 5^2 \cdot 7$ | 2,7202 |
| 1652,5 | 217301 | 276676 | 145531576 | 526 | 22,9347 | 8,0723 | $2 \cdot 263$ | 2,7210 |
| 1655,6 | 218128 | 277729 | 146363183 | 527 | 22,9565 | 8,0774 | $17 \cdot 31$ | 2,7218 |
| 1658,8 | 218956 | 278784 | 147197952 | 528 | 22,9783 | 8,0825 | $2^4 \cdot 3 \cdot 11$ | 2,7226 |
| 1661,9 | 219787 | 279841 | 148035889 | 529 | 23,0000 | 8,0876 | $23^2$ | 2,7235 |
| 1665,0 | 220618 | 280900 | 148877000 | 530 | 23,0217 | 8,0927 | $2 \cdot 5 \cdot 53$ | 2,7243 |
| 1668,2 | 221452 | 281961 | 149721291 | 531 | 23,0434 | 8,0978 | $3^2 \cdot 59$ | 2,7251 |
| 1671,3 | 222287 | 283024 | 150568768 | 532 | 23,0651 | 8,1028 | $2^2 \cdot 7 \cdot 19$ | 2,7259 |
| 1674,5 | 223123 | 284089 | 151419437 | 533 | 23,0868 | 8,1079 | $13 \cdot 41$ | 2,7267 |
| 1677,6 | 223961 | 285156 | 152273304 | 534 | 23,1084 | 8,1130 | $2 \cdot 3 \cdot 89$ | 2,7275 |
| 1680,8 | 224801 | 286225 | 153130375 | 535 | 23,1301 | 8,1180 | $5 \cdot 107$ | 2,7284 |
| 1683,9 | 225642 | 287296 | 153990656 | 536 | 23,1517 | 8,1231 | $2^3 \cdot 67$ | 2,7292 |
| 1687,0 | 226484 | 288369 | 154854153 | 537 | 23,1733 | 8,1281 | $3 \cdot 179$ | 2,7300 |
| 1690,2 | 227329 | 289444 | 155720872 | 538 | 23,1948 | 8,1332 | $2 \cdot 269$ | 2,7303 |
| 1693,3 | 228175 | 290521 | 156590819 | 539 | 23,2164 | 8,1382 | $7^2 \cdot 11$ | 2,7316 |
| 1696,5 | 229022 | 291600 | 157464000 | 540 | 23,2379 | 8,1433 | $2^2 \cdot 3^3 \cdot 5$ | 2,7324 |
| 1699,6 | 229871 | 292681 | 158340421 | 541 | 23,2594 | 8,1483 | — | 2,7332 |
| 1702,7 | 230722 | 293764 | 159220088 | 542 | 23,2809 | 8,1533 | $2 \cdot 271$ | 2,7340 |
| 1705,9 | 231574 | 294849 | 160103007 | 543 | 23,3024 | 8,1583 | $3 \cdot 181$ | 2,7348 |
| 1709,0 | 232428 | 295936 | 160989184 | 544 | 23,3238 | 8,1633 | $2^5 \cdot 17$ | 2,7356 |
| 1712,2 | 233283 | 297025 | 161878625 | 545 | 23,3452 | 8,1683 | $5 \cdot 109$ | 2,7364 |
| 1715,3 | 234140 | 298116 | 162771336 | 546 | 23,3666 | 8,1733 | $2 \cdot 3 \cdot 7 \cdot 13$ | 2,7372 |
| 1718,5 | 234998 | 299209 | 163667323 | 547 | 23,3880 | 8,1783 | — | 2,7380 |
| 1721,6 | 235858 | 300304 | 164566592 | 548 | 23,4094 | 8,1833 | $2^2 \cdot 137$ | 2,7388 |
| 1724,7 | 236720 | 301401 | 165469149 | 549 | 23,4307 | 8,1882 | $3^2 \cdot 61$ | 2,7396 |
| 1727,9 | 237583 | 302500 | 166375000 | 550 | 23,4521 | 8,1932 | $2 \cdot 5^2 \cdot 11$ | 2,7404 |

| $C = \pi \cdot d$ | $A = \frac{\pi \cdot d^2}{4}$ | $A = n^2$ | $V = n^3$ | Number $d$ or $n$ | $\sqrt{n}$ | $\sqrt[3]{n}$ | Factors and primes | lg $n$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 2 | 3 | | $\frac{1}{2}$ | $\frac{1}{3}$ | — | — |
| 1731,0 | 238448 | 303601 | 167284151 | 551 | 23,4734 | 8,1982 | $19 \cdot 29$ | 2,7412 |
| 1734,2 | 239314 | 304704 | 168196608 | 552 | 23,4947 | 8,2031 | $2^3 \cdot 3 \cdot 23$ | 2,7419 |
| 1737,3 | 240182 | 305809 | 169112377 | 553 | 23,5160 | 8,2081 | $7 \cdot 79$ | 2,7427 |
| 1740,4 | 241051 | 306916 | 170031464 | 554 | 23,5372 | 8,2130 | $2 \cdot 277$ | 2,7435 |
| 1743,6 | 241922 | 308025 | 170953875 | 555 | 23,5584 | 8,2180 | $3 \cdot 5 \cdot 37$ | 2,7443 |
| 1746,7 | 242795 | 309136 | 171879616 | 556 | 23,5797 | 8,2229 | $2^2 \cdot 139$ | 2,7451 |
| 1749,9 | 243669 | 310249 | 172808693 | 557 | 23,6008 | 8,2278 | — | 2,7459 |
| 1753,0 | 244545 | 311364 | 173741112 | 558 | 23,6220 | 8,2327 | $2 \cdot 3^2 \cdot 31$ | 2,7466 |
| 1756,2 | 245422 | 312481 | 174676879 | 559 | 23,6432 | 8,2377 | $13 \cdot 43$ | 2,7474 |
| 1759,3 | 246301 | 313600 | 175616000 | 560 | 23,6643 | 8,2426 | $2^4 \cdot 5 \cdot 7$ | 2,7482 |
| 1762,4 | 247181 | 314721 | 176558481 | 561 | 23,6854 | 8,2475 | $3 \cdot 11 \cdot 17$ | 2,7490 |
| 1765,6 | 248063 | 315844 | 177504328 | 562 | 23,7065 | 8,2524 | $2 \cdot 281$ | 2,7497 |
| 1768,7 | 248947 | 316969 | 178453547 | 563 | 23,7276 | 8,2573 | — | 2,7505 |
| 1771,9 | 249832 | 318096 | 179406144 | 564 | 23,7487 | 8,2621 | $2^2 \cdot 3 \cdot 47$ | 2,7513 |
| 1775,0 | 250719 | 319225 | 180362125 | 565 | 23,7697 | 8,2670 | $5 \cdot 113$ | 2,7521 |
| 1778,1 | 251607 | 320356 | 181321496 | 566 | 23,7908 | 8,2719 | $2 \cdot 283$ | 2,7528 |
| 1781,3 | 252497 | 321489 | 182284263 | 567 | 23,8118 | 8,2768 | $3^4 \cdot 7$ | 2,7536 |
| 1784,4 | 253388 | 322624 | 183250432 | 568 | 23,8328 | 8,2816 | $2^3 \cdot 71$ | 2,7544 |
| 1787,6 | 254281 | 323761 | 184220009 | 569 | 23,8537 | 8,2865 | — | 2,7551 |
| 1790,7 | 255176 | 324900 | 185193000 | 570 | 23,8747 | 8,2913 | $2 \cdot 3 \cdot 5 \cdot 19$ | 2,7559 |
| 1793,8 | 256072 | 326041 | 186169411 | 571 | 23,8956 | 8,2962 | — | 2,7566 |
| 1797,0 | 256970 | 327184 | 187149248 | 572 | 23,9165 | 8,3010 | $2^2 \cdot 11 \cdot 13$ | 2,7574 |
| 1800,1 | 257869 | 328329 | 188132517 | 573 | 23,9374 | 8,3059 | $3 \cdot 191$ | 2,7582 |
| 1803,3 | 258770 | 329476 | 189119224 | 574 | 23,9583 | 8,3107 | $2 \cdot 7 \cdot 41$ | 2,7589 |
| 1806,4 | 259672 | 330625 | 190109375 | 575 | 23,9792 | 8,3155 | $5^2 \cdot 23$ | 2,7597 |
| 1809,6 | 260576 | 331776 | 191102976 | 576 | 24,0000 | 8,3203 | $2^6 \cdot 3^2$ | 2,7604 |
| 1812,7 | 261482 | 332929 | 192100033 | 577 | 24,0208 | 8,3251 | — | 2,7612 |
| 1815,8 | 262389 | 334084 | 193100552 | 578 | 24,0416 | 8,3300 | $2 \cdot 17^2$ | 2,7619 |
| 1819,0 | 263298 | 335241 | 194104539 | 579 | 24,0624 | 8,3348 | $3 \cdot 193$ | 2,7627 |
| 1822,1 | 264208 | 336400 | 195112000 | 580 | 24,0832 | 8,3396 | $2^3 \cdot 5 \cdot 29$ | 2,7634 |
| 1825,3 | 265120 | 337561 | 196122941 | 581 | 24,1039 | 8,3443 | $7 \cdot 83$ | 2,7642 |
| 1828,4 | 266033 | 338724 | 197137368 | 582 | 24,1247 | 8,3491 | $2 \cdot 3 \cdot 97$ | 2,7649 |
| 1831,6 | 266948 | 339889 | 198155287 | 583 | 24,1454 | 8,3539 | $11 \cdot 53$ | 2,7657 |
| 1834,7 | 267865 | 341056 | 199176704 | 584 | 24,1661 | 8,3587 | $2^3 \cdot 73$ | 2,7664 |
| 1837,8 | 268783 | 342225 | 200201625 | 585 | 24,1868 | 8,3634 | $3^2 \cdot 5 \cdot 13$ | 2,7672 |
| 1841,0 | 269703 | 343396 | 201230056 | 586 | 24,2074 | 8,3682 | $2 \cdot 293$ | 2,7679 |
| 1844,1 | 270624 | 344569 | 202262003 | 587 | 24,2281 | 8,3730 | — | 2,7686 |
| 1847,3 | 271547 | 345744 | 203297472 | 588 | 24,2487 | 8,3777 | $2^2 \cdot 3 \cdot 7^2$ | 2,7694 |
| 1850,4 | 272471 | 346921 | 204336469 | 589 | 24,2693 | 8,3825 | $19 \cdot 31$ | 2,7701 |
| 1853,5 | 273397 | 348100 | 205379000 | 590 | 24,2899 | 8,3872 | $2 \cdot 5 \cdot 59$ | 2,7709 |
| 1856,7 | 274325 | 349281 | 206425071 | 591 | 24,3105 | 8,3919 | $3 \cdot 197$ | 2,7716 |
| 1859,8 | 275254 | 350464 | 207474688 | 592 | 24,3311 | 8,3967 | $2^4 \cdot 37$ | 2,7723 |
| 1863,0 | 276184 | 351649 | 208527857 | 593 | 24,3516 | 8,4014 | — | 2,7731 |
| 1866,1 | 277117 | 352836 | 209584584 | 594 | 24,3721 | 8,4061 | $2 \cdot 3^3 \cdot 11$ | 2,7738 |
| 1869,2 | 278051 | 354025 | 210644875 | 595 | 24,3926 | 8,4108 | $5 \cdot 7 \cdot 17$ | 2,7745 |
| 1872,4 | 278986 | 355216 | 211708736 | 596 | 24,4131 | 8,4155 | $2^2 \cdot 149$ | 2,7753 |
| 1875,5 | 279923 | 356409 | 212776173 | 597 | 24,4336 | 8,4202 | $3 \cdot 199$ | 2,7760 |
| 1878,7 | 280862 | 357604 | 213847192 | 598 | 24,4540 | 8,4249 | $2 \cdot 13 \cdot 23$ | 2,7767 |
| 1881,8 | 281802 | 358801 | 214921799 | 599 | 24,4745 | 8,4296 | — | 2,7774 |
| 1885,0 | 282743 | 360000 | 216000000 | 600 | 24,4949 | 8,4343 | $2^3 \cdot 3 \cdot 5^2$ | 2,7782 |

551 ... 600

| $C = \pi \cdot d$ | $A = \frac{\pi \cdot d^2}{4}$ | $A = n^2$ |  $V = n^3$ | Number $d$ or $n$ | $\sqrt{n}$ | $\sqrt[3]{n}$ | Factors and primes | lg $n$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 2 | 3 | | $\frac{1}{2}$ | $\frac{1}{3}$ | — | — |
| 1888,1 | 283687 | 361201 | 217081801 | 601 | 24,5153 | 8,4390 | — | 2,7789 |
| 1891,2 | 284631 | 362404 | 218167208 | 602 | 24,5357 | 8,4437 | $2 \cdot 7 \cdot 43$ | 2,7796 |
| 1894,4 | 285578 | 363609 | 219256227 | 603 | 24,5561 | 8,4484 | $3^2 \cdot 67$ | 2,7803 |
| 1897,5 | 286526 | 364816 | 220348864 | 604 | 24,5764 | 8,4530 | $2^2 \cdot 151$ | 2,7810 |
| 1900,7 | 287475 | 366025 | 221445125 | 605 | 24,5967 | 8,4577 | $5 \cdot 11^2$ | 2,7818 |
| 1903,8 | 288426 | 367236 | 222545016 | 606 | 24,6171 | 8,4623 | $2 \cdot 3 \cdot 101$ | 2,7825 |
| 1906,9 | 289379 | 368449 | 223648543 | 607 | 24,6374 | 8,4670 | — | 2,7832 |
| 1910,1 | 290333 | 369664 | 224755712 | 608 | 24,6577 | 8,4716 | $2^5 \cdot 19$ | 2,7839 |
| 1913,2 | 291289 | 370881 | 225866529 | 609 | 24,6779 | 8,4763 | $3 \cdot 7 \cdot 29$ | 2,7846 |
| 1916,4 | 292247 | 372100 | 226981000 | 610 | 24,6982 | 8,4809 | $2 \cdot 5 \cdot 61$ | 2,7853 |
| 1919,5 | 293206 | 373321 | 228099131 | 611 | 24,7184 | 8,4856 | $13 \cdot 47$ | 2,7860 |
| 1922,7 | 294166 | 374544 | 229220928 | 612 | 24,7386 | 8,4902 | $2^2 \cdot 3^2 \cdot 17$ | 2,7868 |
| 1925,8 | 295128 | 375769 | 230346397 | 613 | 24,7588 | 8,4948 | — | 2,7875 |
| 1928,9 | 296092 | 376996 | 231475544 | 614 | 24,7790 | 8,4994 | $2 \cdot 307$ | 2,7882 |
| 1932,1 | 297057 | 378225 | 232608375 | 615 | 24,7992 | 8,5040 | $3 \cdot 5 \cdot 41$ | 2,7889 |
| 1935,2 | 298024 | 379456 | 233744896 | 616 | 24,8193 | 8,5086 | $2^3 \cdot 7 \cdot 11$ | 2,7896 |
| 1938,4 | 298992 | 380689 | 234885113 | 617 | 24,8395 | 8,5132 | — | 2,7903 |
| 1941,5 | 299962 | 381924 | 236029032 | 618 | 24,8596 | 8,5178 | $2 \cdot 3 \cdot 103$ | 2,7910 |
| 1944,6 | 300934 | 383161 | 237176659 | 619 | 24,8797 | 8,5224 | — | 2,7917 |
| 1947,8 | 301907 | 384400 | 238328000 | 620 | 24,8998 | 8,5270 | $2^2 \cdot 5 \cdot 31$ | 2,7924 |
| 1950,9 | 302882 | 385641 | 239483061 | 621 | 24,9199 | 8,5316 | $3^3 \cdot 23$ | 2,7931 |
| 1954,1 | 303858 | 386884 | 240641848 | 622 | 24,9399 | 8,5362 | $2 \cdot 311$ | 2,7938 |
| 1957,2 | 304836 | 388129 | 241804367 | 623 | 24,9600 | 8,5408 | $7 \cdot 89$ | 2,7945 |
| 1960,4 | 305815 | 389376 | 242970624 | 624 | 24,9800 | 8,5453 | $2^4 \cdot 3 \cdot 13$ | 2,7952 |
| 1963,5 | 306796 | 390625 | 244140625 | 625 | 25,0000 | 8,5499 | $5^4$ | 2,7959 |
| 1966,6 | 307779 | 391876 | 245314376 | 626 | 25,0200 | 8,5544 | $2 \cdot 313$ | 2,7966 |
| 1969,8 | 308763 | 393129 | 246491883 | 627 | 25,0400 | 8,5590 | $3 \cdot 11 \cdot 19$ | 2,7973 |
| 1972,9 | 309748 | 394384 | 247673152 | 628 | 25,0599 | 8,5635 | $2^2 \cdot 157$ | 2,7980 |
| 1976,1 | 310736 | 395641 | 248858189 | 629 | 25,0799 | 8,5681 | $17 \cdot 37$ | 2,7987 |
| 1979,2 | 311725 | 396900 | 250047000 | 630 | 25,0998 | 8,5726 | $2 \cdot 3^2 \cdot 5 \cdot 7$ | 2,7993 |
| 1982,3 | 312715 | 398161 | 251239591 | 631 | 25,1197 | 8,5772 | — | 2,8000 |
| 1985,5 | 313707 | 399424 | 252435968 | 632 | 25,1396 | 8,5817 | $2^3 \cdot 79$ | 2,8007 |
| 1988,6 | 314700 | 400689 | 253636137 | 633 | 25,1595 | 8,5862 | $3 \cdot 211$ | 2,8014 |
| 1991,8 | 315696 | 401956 | 254840104 | 634 | 25,1794 | 8,5907 | $2 \cdot 317$ | 2,8021 |
| 1994,9 | 316692 | 403225 | 256047875 | 635 | 25,1992 | 8,5952 | $5 \cdot 127$ | 2,8028 |
| 1998,1 | 317690 | 404496 | 257259456 | 636 | 25,2190 | 8,5997 | $2^2 \cdot 3 \cdot 53$ | 2,8035 |
| 2001,2 | 318690 | 405769 | 258474853 | 637 | 25,2389 | 8,6043 | $7^2 \cdot 13$ | 2,8041 |
| 2004,3 | 319692 | 407044 | 259694072 | 638 | 25,2587 | 8,6088 | $2 \cdot 11 \cdot 29$ | 2,8048 |
| 2007,5 | 320695 | 408321 | 260917119 | 639 | 25,2784 | 8,6132 | $3^2 \cdot 71$ | 2,8055 |
| 2010,6 | 321699 | 409600 | 262144000 | 640 | 25,2982 | 8,6177 | $2^7 \cdot 5$ | 2,8062 |
| 2013,8 | 322705 | 410881 | 263374721 | 641 | 25,3180 | 8,6222 | — | 2,8069 |
| 2016,9 | 323713 | 412164 | 264609288 | 642 | 25,3377 | 8,6267 | $2 \cdot 3 \cdot 107$ | 2,8075 |
| 2020,0 | 324722 | 413449 | 265847707 | 643 | 25,3574 | 8,6312 | — | 2,8082 |
| 2023,2 | 325733 | 414736 | 267089984 | 644 | 25,3772 | 8,6357 | $2^2 \cdot 7 \cdot 23$ | 2,8089 |
| 2026,3 | 326745 | 416025 | 268336125 | 645 | 25,3969 | 8,6401 | $3 \cdot 5 \cdot 43$ | 2,8096 |
| 2029,5 | 327759 | 417316 | 269586136 | 646 | 25,4165 | 8,6446 | $2 \cdot 17 \cdot 19$ | 2,8102 |
| 2032,6 | 328775 | 418609 | 270840023 | 647 | 25,4362 | 8,6490 | — | 2,8109 |
| 2035,8 | 329792 | 419904 | 272097792 | 648 | 25,4558 | 8,6535 | $2^3 \cdot 3^4$ | 2,8116 |
| 2038,9 | 330810 | 421201 | 273359449 | 649 | 25,4755 | 8,6579 | $11 \cdot 59$ | 2,8122 |
| 2042,0 | 331831 | 422500 | 274625000 | 650 | 25,4951 | 8,6624 | $2 \cdot 5^3 \cdot 13$ | 2,8129 |

651 ... 700

| $C = \pi \cdot d$ | $A = \frac{\pi \cdot d^2}{4}$ | $A = n^2$ | $V = n^3$ | Number $d$ or $n$ | $\sqrt{n}$ | $\sqrt[3]{n}$ | Factors and primes | lg $n$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 2 | 3 | | $\frac{1}{2}$ | $\frac{1}{3}$ | — | — |
| 2045,2 | 332853 | 423801 | 275894451 | 651 | 25,5147 | 8,6668 | $3 \cdot 7 \cdot 31$ | 2,8136 |
| 2048,3 | 333876 | 425104 | 277167808 | 652 | 25,5343 | 8,6713 | $2^2 \cdot 163$ | 2,8143 |
| 2051,5 | 334901 | 426409 | 278445077 | 653 | 25,5539 | 8,6757 | — | 2,8149 |
| 2054,6 | 335927 | 427716 | 279726264 | 654 | 25,5734 | 8,6801 | $2 \cdot 3 \cdot 109$ | 2,8156 |
| 2057,7 | 336955 | 429025 | 281011375 | 655 | 25,5930 | 8,6845 | $5 \cdot 131$ | 2,8162 |
| 2060,9 | 337985 | 430336 | 282300416 | 656 | 25,6125 | 8,6890 | $2^4 \cdot 41$ | 2,8169 |
| 2064,0 | 339016 | 431649 | 283593393 | 657 | 25,6320 | 8,6934 | $3^2 \cdot 73$ | 2,8176 |
| 2067,2 | 340049 | 432964 | 284890312 | 658 | 25,6515 | 8,6978 | $2 \cdot 7 \cdot 47$ | 2,8182 |
| 2070,3 | 341083 | 434281 | 286191179 | 659 | 25,6710 | 8,7022 | — | 2,8189 |
| 2073,5 | 342119 | 435600 | 287496000 | 660 | 25,6905 | 8,7066 | $2^2 \cdot 3 \cdot 5 \cdot 11$ | 2,8195 |
| 2076,6 | 343157 | 436921 | 288804781 | 661 | 25,7099 | 8,7110 | — | 2,8202 |
| 2079,7 | 344196 | 438244 | 290117528 | 662 | 25,7294 | 8,7154 | $2 \cdot 331$ | 2,8209 |
| 2082,9 | 345237 | 439569 | 291434247 | 663 | 25,7488 | 8,7198 | $3 \cdot 13 \cdot 17$ | 2,8215 |
| 2086,0 | 346279 | 440896 | 292754944 | 664 | 25,7682 | 8,7241 | $2^3 \cdot 83$ | 2,8222 |
| 2089,2 | 347323 | 442225 | 294079625 | 665 | 25,7876 | 8,7285 | $5 \cdot 7 \cdot 19$ | 2,8228 |
| 2092,3 | 348368 | 443556 | 295408296 | 666 | 25,8070 | 8,7329 | $2 \cdot 3^2 \cdot 37$ | 2,8235 |
| 2095,4 | 349415 | 444889 | 296740963 | 667 | 25,8263 | 8,7373 | $23 \cdot 29$ | 2,8241 |
| 2098,6 | 350464 | 446224 | 298077632 | 668 | 25,8457 | 8,7416 | $2^2 \cdot 167$ | 2,8248 |
| 2101,7 | 351514 | 447561 | 299418309 | 669 | 25,8650 | 8,7460 | $3 \cdot 223$ | 2,8254 |
| 2104,9 | 352565 | 448900 | 300763000 | 670 | 25,8844 | 8,7503 | $2 \cdot 5 \cdot 67$ | 2,8261 |
| 2108,0 | 353618 | 450241 | 302111711 | 671 | 25,9037 | 8,7547 | $11 \cdot 61$ | 2,8267 |
| 2111,2 | 354673 | 451584 | 303464448 | 672 | 25,9230 | 8,7590 | $2^5 \cdot 3 \cdot 7$ | 2,8274 |
| 2114,3 | 355730 | 452929 | 304821217 | 673 | 25,9422 | 8,7634 | — | 2,8280 |
| 2117,4 | 356788 | 454276 | 306182024 | 674 | 25,9615 | 8,7677 | $2 \cdot 337$ | 2,8287 |
| 2120,6 | 357847 | 455625 | 307546875 | 675 | 25,9808 | 8,7721 | $3^3 \cdot 5^2$ | 2,8293 |
| 2123,7 | 358908 | 456976 | 308915776 | 676 | 26,0000 | 8,7764 | $2^2 \cdot 13^2$ | 2,8300 |
| 2126,9 | 359971 | 458329 | 310288733 | 677 | 26,0192 | 8,7807 | — | 2,8306 |
| 2130,0 | 361035 | 459684 | 311665752 | 678 | 26,0384 | 8,7850 | $2 \cdot 3 \cdot 113$ | 2,8312 |
| 2133,1 | 362101 | 461041 | 313046839 | 679 | 26,0576 | 8,7893 | $7 \cdot 97$ | 2,8319 |
| 2136,3 | 363168 | 462400 | 314432000 | 680 | 26,0768 | 8,7937 | $2^3 \cdot 5 \cdot 17$ | 2,8325 |
| 2139,4 | 364237 | 463761 | 315821241 | 681 | 26,0960 | 8,7980 | $3 \cdot 227$ | 2,8332 |
| 2142,6 | 365308 | 465124 | 317214568 | 682 | 26,1151 | 8,8023 | $2 \cdot 11 \cdot 31$ | 2,8338 |
| 2145,7 | 366380 | 466489 | 318611987 | 683 | 26,1343 | 8,8066 | — | 2,8344 |
| 2148,8 | 367453 | 467856 | 320013504 | 684 | 26,1534 | 8,8109 | $2^2 \cdot 3^2 \cdot 19$ | 2,8351 |
| 2152,0 | 368528 | 469225 | 321419125 | 685 | 26,1725 | 8,8152 | $5 \cdot 137$ | 2,8357 |
| 2155,1 | 369605 | 470596 | 322828856 | 686 | 26,1916 | 8,8194 | $2 \cdot 7^2$ | 2,8363 |
| 2158,3 | 370684 | 471969 | 324242703 | 687 | 26,2107 | 8,8237 | $3 \cdot 229$ | 2,8370 |
| 2161,4 | 371764 | 473344 | 325660672 | 688 | 26,2298 | 8,8280 | $2^4 \cdot 43$ | 2,8376 |
| 2164,6 | 372845 | 474721 | 327082769 | 689 | 26,2488 | 8,8323 | $13 \cdot 53$ | 2,8382 |
| 2167,7 | 373928 | 476100 | 328509000 | 690 | 26,2679 | 8,8366 | $2 \cdot 3 \cdot 5 \cdot 23$ | 2,8389 |
| 2170,8 | 375013 | 477481 | 329939371 | 691 | 26,2869 | 8,8408 | — | 2,8395 |
| 2174,0 | 376099 | 478864 | 331373888 | 692 | 26,3059 | 8,8451 | $2^2 \cdot 173$ | 2,8401 |
| 2177,1 | 377187 | 480249 | 332812557 | 693 | 26,3249 | 8,8493 | $3^2 \cdot 7 \cdot 11$ | 2,8407 |
| 2180,3 | 378276 | 481636 | 334255384 | 694 | 26,3439 | 8,8536 | $2 \cdot 347$ | 2,8414 |
| 2183,4 | 379367 | 483025 | 335702375 | 695 | 26,3629 | 8,8578 | $5 \cdot 139$ | 2,8420 |
| 2186,5 | 380459 | 484416 | 337153536 | 696 | 26,3818 | 8,8621 | $2^3 \cdot 3 \cdot 29$ | 2,8426 |
| 2189,7 | 381553 | 485809 | 338608873 | 697 | 26,4008 | 8,8663 | $17 \cdot 41$ | 2,8432 |
| 2192,8 | 382649 | 487204 | 340068392 | 698 | 26,4197 | 8,8706 | $2 \cdot 349$ | 2,8439 |
| 2196,0 | 383746 | 488601 | 341532099 | 699 | 26,4386 | 8,8748 | $3 \cdot 233$ | 2,8445 |
| 2199,1 | 384845 | 490000 | 343000000 | 700 | 26,4575 | 8,8790 | $2^2 \cdot 5^2 \cdot 7$ | 2,8451 |

| $C = \pi \cdot d$ | $A = \frac{\pi \cdot d^2}{4}$ | $A = n^2$ | $V = n^3$ | Number $d$ or $n$ | $\sqrt{n}$ | $\sqrt[3]{n}$ | Factors and primes | lg $n$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 2 | 3 | | $\frac{1}{2}$ | $\frac{1}{3}$ | — | — |
| 2202,3 | 385945 | 491401 | 344472101 | 701 | 26,4764 | 8,8833 | — | 2,8457 |
| 2205,4 | 387047 | 492804 | 345948408 | 702 | 26,4953 | 8,8875 | $2 \cdot 3^3 \cdot 13$ | 2,8463 |
| 2208,5 | 388151 | 494209 | 347428927 | 703 | 26,5141 | 8,8917 | $19 \cdot 37$ | 2,8470 |
| 2211,7 | 389256 | 495616 | 348913664 | 704 | 26,5330 | 8,8959 | $2^6 \cdot 11$ | 2,8476 |
| 2214,8 | 390363 | 497025 | 350402625 | 705 | 26,5518 | 8,9001 | $3 \cdot 5 \cdot 47$ | 2,8482 |
| 2218,0 | 391471 | 498436 | 351895816 | 706 | 26,5707 | 8,9043 | $2 \cdot 353$ | 2,8488 |
| 2221,1 | 392580 | 499849 | 353393243 | 707 | 26,5895 | 8,9085 | $7 \cdot 101$ | 2,8494 |
| 2224,2 | 393692 | 501264 | 354894912 | 708 | 26,6083 | 8,9127 | $2^2 \cdot 3 \cdot 59$ | 2,8500 |
| 2227,4 | 394805 | 502681 | 356400829 | 709 | 26,6271 | 8,9169 | — | 2,8507 |
| 2230,5 | 395919 | 504100 | 357911000 | 710 | 26,6458 | 8,9211 | $2 \cdot 5 \cdot 71$ | 2,8513 |
| 2233,7 | 397035 | 505521 | 359425431 | 711 | 26,6646 | 8,9253 | $3^2 \cdot 79$ | 2,8519 |
| 2236,8 | 398153 | 506944 | 360944128 | 712 | 26,6833 | 8,9295 | $2^3 \cdot 89$ | 2,8525 |
| 2240,0 | 399272 | 508369 | 362467097 | 713 | 26,7021 | 8,9337 | $23 \cdot 31$ | 2,8531 |
| 2243,1 | 400393 | 509796 | 363994344 | 714 | 26,7208 | 8,9378 | $2 \cdot 3 \cdot 7 \cdot 17$ | 2,8537 |
| 2246,2 | 401515 | 511225 | 365525875 | 715 | 26,7395 | 8,9420 | $5 \cdot 11 \cdot 13$ | 2,8543 |
| 2249,4 | 402639 | 512656 | 367061696 | 716 | 26,7582 | 8,9462 | $2^2 \cdot 179$ | 2,8549 |
| 2252,5 | 403765 | 514089 | 368601813 | 717 | 26,7769 | 8,9503 | $3 \cdot 239$ | 2,8555 |
| 2255,7 | 404892 | 515524 | 370146232 | 718 | 26,7955 | 8,9545 | $2 \cdot 359$ | 2,8561 |
| 2258,8 | 406020 | 516961 | 371694959 | 719 | 26,8142 | 8,9587 | — | 2,8567 |
| 2261,9 | 407150 | 518400 | 373248000 | 720 | 26,8328 | 8,9628 | $2^4 \cdot 3^2 \cdot 5$ | 2,8573 |
| 2265,1 | 408282 | 519841 | 374805361 | 721 | 26,8514 | 8,9670 | $7 \cdot 103$ | 2,8579 |
| 2268,2 | 409415 | 521284 | 376367048 | 722 | 26,8701 | 8,9711 | $2 \cdot 19^2$ | 2,8585 |
| 2271,4 | 410550 | 522729 | 377933067 | 723 | 26,8887 | 8,9752 | $3 \cdot 241$ | 2,8591 |
| 2274,5 | 411687 | 524176 | 379503424 | 724 | 26,9072 | 8,9794 | $2^2 \cdot 181$ | 2,8597 |
| 2277,7 | 412825 | 525625 | 381078125 | 725 | 26,9258 | 8,9835 | $5^2 \cdot 29$ | 2,8603 |
| 2280,8 | 413965 | 527076 | 382657176 | 726 | 26,9444 | 8,9876 | $2 \cdot 3 \cdot 11^2$ | 2,8609 |
| 2283,9 | 415106 | 528529 | 384240583 | 727 | 26,9629 | 8,9918 | — | 2,8615 |
| 2287,1 | 416248 | 529984 | 385828352 | 728 | 26,9815 | 8,9959 | $2^3 \cdot 7 \cdot 13$ | 2,8621 |
| 2290,2 | 417393 | 531441 | 387420489 | 729 | 27,0000 | 9,0000 | $3^6$ | 2,8627 |
| 2293,4 | 418539 | 532900 | 389017000 | 730 | 27,0185 | 9,0041 | $2 \cdot 5 \cdot 73$ | 2,8633 |
| 2296,5 | 419686 | 534361 | 390617891 | 731 | 27,0370 | 9,0082 | $17 \cdot 43$ | 2,8639 |
| 2299,6 | 420835 | 535824 | 392223168 | 732 | 27,0555 | 9,0123 | $2^2 \cdot 3 \cdot 61$ | 2,8645 |
| 2302,8 | 421986 | 537289 | 393832837 | 733 | 27,0740 | 9,0164 | — | 2,8651 |
| 2305,9 | 423138 | 538756 | 395446904 | 734 | 27,0924 | 9,0205 | $2 \cdot 367$ | 2,8657 |
| 2309,1 | 424293 | 540225 | 397065375 | 735 | 27,1109 | 9,0246 | $3 \cdot 5 \cdot 7^2$ | 2,8663 |
| 2312,2 | 425447 | 541696 | 398688256 | 736 | 27,1293 | 9,0287 | $2^5 \cdot 23$ | 2,8669 |
| 2315,4 | 426604 | 543169 | 400315553 | 737 | 27,1477 | 9,0328 | $11 \cdot 67$ | 2,8675 |
| 2318,5 | 427762 | 544644 | 401947272 | 738 | 27,1662 | 9,0369 | $2 \cdot 3^2 \cdot 41$ | 2,8681 |
| 2321,6 | 428922 | 546121 | 403583419 | 739 | 27,1846 | 9,0410 | — | 2,8686 |
| 2324,8 | 430084 | 547600 | 405224000 | 740 | 27,2029 | 9,0450 | $2^2 \cdot 5 \cdot 37$ | 2,8692 |
| 2327,9 | 431247 | 549081 | 406869021 | 741 | 27,2213 | 9,0491 | $3 \cdot 13 \cdot 19$ | 2,8698 |
| 2331,1 | 432412 | 550564 | 408518488 | 742 | 27,2397 | 9,0532 | $2 \cdot 7 \cdot 53$ | 2,8704 |
| 2334,2 | 433578 | 552049 | 410172407 | 743 | 27,2580 | 9,0572 | — | 2,8710 |
| 2337,3 | 434746 | 553536 | 411830784 | 744 | 27,2764 | 9,0613 | $2^3 \cdot 3 \cdot 31$ | 2,8716 |
| 2340,5 | 435916 | 555025 | 413493625 | 745 | 27,2947 | 9,0654 | $5 \cdot 149$ | 2,8722 |
| 2343,6 | 437087 | 556516 | 415160936 | 746 | 27,3130 | 9,0694 | $2 \cdot 373$ | 2,8727 |
| 2346,8 | 438259 | 558009 | 416832723 | 747 | 27,3313 | 9,0735 | $3^2 \cdot 83$ | 2,8733 |
| 2349,9 | 439433 | 559504 | 418508992 | 748 | 27,3496 | 9,0775 | $2^2 \cdot 11 \cdot 17$ | 2,8739 |
| 2353,1 | 440609 | 561001 | 420189749 | 749 | 27,3679 | 9,0816 | $7 \cdot 107$ | 2,8745 |
| 2356,2 | 441786 | 562500 | 421875000 | 750 | 27,3861 | 9,0856 | $2 \cdot 3 \cdot 5^3$ | 2,8751 |

| $C = \pi \cdot d$ | $A = \frac{\pi \cdot d^2}{4}$ | $A = n^2$ | $V = n^3$ | Number $d$ or $n$ | $\sqrt{n}$ | $\sqrt[3]{n}$ | Factors and primes | lg $n$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 2 | 3 | | $\frac{1}{2}$ | $\frac{1}{3}$ | — | — |
| 2359,3 | 442965 | 564001 | 423564751 | 751 | 27,4044 | 9,0896 | — | 2,8756 |
| 2362,5 | 444146 | 565504 | 425259008 | 752 | 27,4226 | 9,0937 | $2^4 \cdot 47$ | 2,8762 |
| 2365,6 | 445328 | 567009 | 426957777 | 753 | 27,4408 | 9,0977 | $3 \cdot 251$ | 2,8768 |
| 2368,8 | 446511 | 568516 | 428661064 | 754 | 27,4591 | 9,1017 | $2 \cdot 13 \cdot 29$ | 2,8774 |
| 2371,9 | 447697 | 570025 | 430368875 | 755 | 27,4773 | 9,1057 | $5 \cdot 151$ | 2,8780 |
| 2375,0 | 448883 | 571536 | 432081216 | 756 | 27,4955 | 9,1098 | $2^2 \cdot 3^3 \cdot 7$ | 2,8785 |
| 2378,2 | 450072 | 573049 | 433798093 | 757 | 27,5136 | 9,1138 | — | 2,8791 |
| 2381,3 | 451262 | 574564 | 435519512 | 758 | 27,5318 | 9,1178 | $2 \cdot 379$ | 2,8797 |
| 2384,5 | 452453 | 576081 | 437245479 | 759 | 27,5500 | 9,1218 | $3 \cdot 11 \cdot 23$ | 2,8802 |
| 2387,6 | 453646 | 577600 | 438976000 | 760 | 27,5681 | 9,1258 | $2^3 \cdot 5 \cdot 19$ | 2,8808 |
| 2390,8 | 454841 | 579121 | 440711081 | 761 | 27,5862 | 9,1298 | — | 2,8814 |
| 2393,9 | 456037 | 580644 | 442450728 | 762 | 27,6043 | 9,1338 | $2 \cdot 3 \cdot 127$ | 2,8820 |
| 2397,0 | 457234 | 582169 | 444194947 | 763 | 27,6225 | 9,1378 | $7 \cdot 109$ | 2,8825 |
| 2400,2 | 458434 | 583696 | 445943744 | 764 | 27,6405 | 9,1418 | $2^2 \cdot 191$ | 2,8831 |
| 2403,3 | 459635 | 585225 | 447697125 | 765 | 27,6586 | 9,1458 | $3^2 \cdot 5 \cdot 17$ | 2,8837 |
| 2406,5 | 460837 | 586756 | 449455096 | 766 | 27,6767 | 9,1498 | $2 \cdot 383$ | 2,8842 |
| 2409,6 | 462041 | 588289 | 451217663 | 767 | 27,6948 | 9,1537 | $13 \cdot 59$ | 2,8848 |
| 2412,7 | 463247 | 589824 | 452984832 | 768 | 27,7128 | 9,1577 | $2^8 \cdot 3$ | 2,8854 |
| 2415,9 | 464454 | 591361 | 454756609 | 769 | 27,7308 | 9,1617 | — | 2,8859 |
| 2419,0 | 465663 | 592900 | 456533000 | 770 | 27,7489 | 9,1657 | $2 \cdot 5 \cdot 7 \cdot 11$ | 2,8865 |
| 2422,2 | 466873 | 594441 | 458314011 | 771 | 27,7669 | 9,1696 | $3 \cdot 257$ | 2,8871 |
| 2425,3 | 468085 | 595984 | 460099648 | 772 | 27,7849 | 9,1736 | $2^2 \cdot 193$ | 2,8876 |
| 2428,5 | 469298 | 597529 | 461889917 | 773 | 27,8029 | 9,1775 | — | 2,8882 |
| 2431,6 | 470513 | 599076 | 463684824 | 774 | 27,8209 | 9,1815 | $2 \cdot 3^2 \cdot 43$ | 2,8887 |
| 2434,7 | 471730 | 600625 | 465484375 | 775 | 27,8388 | 9,1855 | $5^2 \cdot 31$ | 2,8893 |
| 2437,9 | 472948 | 602176 | 467288576 | 776 | 27,8568 | 9,1894 | $2^3 \cdot 97$ | 2,8899 |
| 2441,0 | 474168 | 603729 | 469097433 | 777 | 27,8747 | 9,1933 | $3 \cdot 7 \cdot 37$ | 2,8904 |
| 2444,2 | 475389 | 605284 | 470910952 | 778 | 27,8927 | 9,1973 | $2 \cdot 389$ | 2,8910 |
| 2447,3 | 476612 | 606841 | 472729139 | 779 | 27,9106 | 9,2012 | $19 \cdot 41$ | 2,8915 |
| 2450,4 | 477836 | 608400 | 474552000 | 780 | 27,9285 | 9,2052 | $2^2 \cdot 3 \cdot 5 \cdot 13$ | 2,8921 |
| 2453,6 | 479062 | 609961 | 476379541 | 781 | 27,9464 | 9,2091 | $11 \cdot 71$ | 2,8927 |
| 2456,7 | 480290 | 611524 | 478211768 | 782 | 27,9643 | 9,2130 | $2 \cdot 17 \cdot 23$ | 2,8932 |
| 2459,9 | 481519 | 613089 | 480048687 | 783 | 27,9821 | 9,2170 | $3^3 \cdot 29$ | 2,8938 |
| 2463,0 | 482750 | 614656 | 481890304 | 784 | 28,0000 | 9,2209 | $2^4 \cdot 7^2$ | 2,8943 |
| 2466,2 | 483982 | 616225 | 483736625 | 785 | 28,0179 | 9,2248 | $5 \cdot 157$ | 2,8949 |
| 2469,3 | 485216 | 617796 | 485587656 | 786 | 28,0357 | 9,2287 | $2 \cdot 3 \cdot 131$ | 2,8954 |
| 2472,4 | 486451 | 619369 | 487443403 | 787 | 28,0535 | 9,2326 | — | 2,8960 |
| 2475,6 | 487688 | 620944 | 489303872 | 788 | 28,0713 | 9,2365 | $2^2 \cdot 197$ | 2,8965 |
| 2478,7 | 488927 | 622521 | 491169069 | 789 | 28,0891 | 9,2404 | $3 \cdot 263$ | 2,8971 |
| 2481,9 | 490167 | 624100 | 493039000 | 790 | 28,1069 | 9,2443 | $2 \cdot 5 \cdot 79$ | 2,8976 |
| 2485,0 | 491409 | 625681 | 494913671 | 791 | 28,1247 | 9,2482 | $7 \cdot 113$ | 2,8982 |
| 2488,1 | 492652 | 627264 | 496793088 | 792 | 28,1425 | 9,2521 | $2^3 \cdot 3^2 \cdot 11$ | 2,8987 |
| 2491,3 | 493897 | 628849 | 498677257 | 793 | 28,1603 | 9,2560 | $13 \cdot 61$ | 2,8993 |
| 2494,4 | 495143 | 630436 | 500566184 | 794 | 28,1780 | 9,2599 | $2 \cdot 397$ | 2,8998 |
| 2497,6 | 496391 | 632025 | 502459875 | 795 | 28,1957 | 9,2638 | $3 \cdot 5 \cdot 53$ | 2,9004 |
| 2500,7 | 497641 | 633616 | 504358336 | 796 | 28,2135 | 9,2677 | $2^2 \cdot 199$ | 2,9009 |
| 2503,8 | 498892 | 635209 | 506261573 | 797 | 28,2312 | 9,2716 | — | 2,9015 |
| 2507,0 | 500145 | 636804 | 508169592 | 798 | 28,2489 | 9,2754 | $2 \cdot 3 \cdot 7 \cdot 19$ | 2,9020 |
| 2510,1 | 501399 | 638401 | 510082399 | 799 | 28,2666 | 9,2793 | $17 \cdot 47$ | 2,9026 |
| 2513,3 | 502655 | 640000 | 512000000 | 800 | 28,2843 | 9,2832 | $2^8 \cdot 5^3$ | 2,9031 |

751 ... 800

| $C = \pi \cdot d$ | $A = \frac{\pi \cdot d^2}{4}$ | $A = n^2$ | $V = n^3$ | Number $d$ or $n$ | $\sqrt{n}$ | $\sqrt[3]{n}$ | Factors and primes | lg $n$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 2 | 3 | | $\frac{1}{2}$ | $\frac{1}{3}$ | — | — |
| 2516,4 | 503912 | 641601 | 513922401 | 801 | 28,3019 | 9,2870 | $3^2 \cdot 89$ | 2,9036 |
| 2519,6 | 505171 | 643204 | 515849608 | 802 | 28,3196 | 9,2909 | $2 \cdot 401$ | 2,9042 |
| 2522,7 | 506432 | 644809 | 517781627 | 803 | 28,3373 | 9,2948 | $11 \cdot 73$ | 2,9047 |
| 2525,8 | 507694 | 646416 | 519718464 | 804 | 28,3549 | 9,2986 | $2^2 \cdot 3 \cdot 67$ | 2,9053 |
| 2529,0 | 508958 | 648025 | 521660125 | 805 | 28,3725 | 9,3025 | $5 \cdot 7 \cdot 23$ | 2,9058 |
| 2532,1 | 510223 | 649636 | 523606616 | 806 | 28,3901 | 9,3063 | $2 \cdot 13 \cdot 31$ | 2,9063 |
| 2535,3 | 511490 | 651249 | 525557943 | 807 | 28,4077 | 9,3102 | $3 \cdot 269$ | 2,9069 |
| 2538,4 | 512758 | 652864 | 527514112 | 808 | 28,4253 | 9,3140 | $2^3 \cdot 101$ | 2,9074 |
| 2541,5 | 514028 | 654481 | 529475129 | 809 | 28,4429 | 9,3179 | — | 2,9080 |
| 2544,7 | 515300 | 656100 | 531441000 | 810 | 28,4605 | 9,3217 | $2 \cdot 3^4 \cdot 5$ | 2,9085 |
| 2547,8 | 516573 | 657721 | 533411731 | 811 | 28,4781 | 9,3255 | — | 2,9090 |
| 2551,0 | 517848 | 659344 | 535387328 | 812 | 28,4956 | 9,3294 | $2^2 \cdot 7 \cdot 29$ | 2,9096 |
| 2554,1 | 519124 | 660969 | 537367797 | 813 | 28,5132 | 9,3332 | $3 \cdot 271$ | 2,9101 |
| 2557,3 | 520402 | 662596 | 539353144 | 814 | 28,5307 | 9,3370 | $2 \cdot 11 \cdot 37$ | 2,9106 |
| 2560,4 | 521681 | 664225 | 541343375 | 815 | 28,5482 | 9,3408 | $5 \cdot 163$ | 2,9112 |
| 2563,5 | 522962 | 665856 | 543338496 | 816 | 28,5657 | 9,3447 | $2^4 \cdot 3 \cdot 17$ | 2,9117 |
| 2566,7 | 524245 | 667489 | 545338513 | 817 | 28,5832 | 9,3485 | $19 \cdot 43$ | 2,9122 |
| 2569,8 | 525529 | 669124 | 547343432 | 818 | 28,6007 | 9,3523 | $2 \cdot 409$ | 2,9128 |
| 2573,0 | 526814 | 670761 | 549353259 | 819 | 28,6182 | 9,3561 | $3^2 \cdot 7 \cdot 13$ | 2,9133 |
| 2576,1 | 528102 | 672400 | 551368000 | 820 | 28,6356 | 9,3599 | $2^3 \cdot 5 \cdot 41$ | 2,9138 |
| 2579,2 | 529391 | 674041 | 553387661 | 821 | 28,6531 | 9,3637 | — | 2,9143 |
| 2582,4 | 530681 | 675684 | 555412248 | 822 | 28,6705 | 9,3675 | $2 \cdot 3 \cdot 137$ | 2,9149 |
| 2585,5 | 531973 | 677329 | 557441767 | 823 | 28,6880 | 9,3713 | — | 2,9154 |
| 2588,7 | 533267 | 678976 | 559476224 | 824 | 28,7054 | 9,3751 | $2^3 \cdot 103$ | 2,9159 |
| 2591,8 | 534562 | 680625 | 561515625 | 825 | 28,7228 | 9,3789 | $3 \cdot 5^2 \cdot 11$ | 2,9165 |
| 2595,0 | 535858 | 682276 | 563559976 | 826 | 28,7402 | 9,3827 | $2 \cdot 7 \cdot 59$ | 2,9170 |
| 2598,1 | 537157 | 683929 | 565609283 | 827 | 28,7576 | 9,3865 | — | 2,9175 |
| 2601,2 | 538456 | 685584 | 567663552 | 828 | 28,7750 | 9,3902 | $2^2 \cdot 3^2 \cdot 23$ | 2,9180 |
| 2604,4 | 539758 | 687241 | 569722789 | 829 | 28,7924 | 9,3940 | — | 2,9186 |
| 2607,5 | 541061 | 688900 | 571787000 | 830 | 28,8097 | 9,3978 | $2 \cdot 5 \cdot 83$ | 2,9191 |
| 2610,7 | 542365 | 690561 | 573856191 | 831 | 28,8271 | 9,4016 | $3 \cdot 277$ | 2,9196 |
| 2613,8 | 543671 | 692224 | 575930368 | 832 | 28,8444 | 9,4053 | $2^6 \cdot 13$ | 2,9201 |
| 2616,9 | 544979 | 693889 | 578009537 | 833 | 28,8617 | 9,4091 | $7^2 \cdot 17$ | 2,9207 |
| 2620,1 | 546288 | 695556 | 580093704 | 834 | 28,8791 | 9,4129 | $2 \cdot 3 \cdot 139$ | 2,9212 |
| 2623,2 | 547599 | 697225 | 582182875 | 835 | 28,8964 | 9,4166 | $5 \cdot 167$ | 2,9217 |
| 2626,4 | 548912 | 698896 | 584277056 | 836 | 28,9137 | 9,4204 | $2^2 \cdot 11 \cdot 17$ | 2,9222 |
| 2629,5 | 550226 | 700569 | 586376253 | 837 | 28,9310 | 9,4241 | $3^3 \cdot 31$ | 2,9227 |
| 2632,7 | 551541 | 702244 | 588480472 | 838 | 28,9482 | 9,4279 | $2 \cdot 419$ | 2,9232 |
| 2635,8 | 552858 | 703921 | 590589719 | 839 | 28,9655 | 9,4316 | — | 2,9239 |
| 2638,9 | 554177 | 705600 | 592704000 | 840 | 28,9828 | 9,4354 | $2^3 \cdot 3 \cdot 5 \cdot 7$ | 2,9243 |
| 2642,1 | 555497 | 707281 | 594823321 | 841 | 29,0000 | 9,4391 | $29^2$ | 2,9248 |
| 2645,2 | 556819 | 708964 | 596947688 | 842 | 29,0172 | 9,4429 | $2 \cdot 421$ | 2,9253 |
| 2648,4 | 558142 | 710649 | 599077107 | 843 | 29,0345 | 9,4466 | $3 \cdot 281$ | 2,9258 |
| 2651,5 | 559467 | 712336 | 601211584 | 844 | 29,0517 | 9,4503 | $2^2 \cdot 211$ | 2,9263 |
| 2654,6 | 560794 | 714025 | 603351125 | 845 | 29,0689 | 9,4541 | $5 \cdot 13^2$ | 2,9269 |
| 2657,8 | 562122 | 715716 | 605495736 | 846 | 29,0861 | 9,4578 | $2 \cdot 3^2 \cdot 47$ | 2,9274 |
| 2660,9 | 563452 | 717409 | 607645423 | 847 | 29,1033 | 9,4615 | $7 \cdot 11^2$ | 2,9279 |
| 2664,1 | 564783 | 719104 | 609800192 | 848 | 29,1204 | 9,4652 | $2^4 \cdot 53$ | 2,9284 |
| 2667,2 | 566116 | 720801 | 611960049 | 849 | 29,1376 | 9,4690 | $3 \cdot 283$ | 2,9289 |
| 2670,4 | 567450 | 722500 | 614125000 | 850 | 29,1548 | 9,4727 | $2 \cdot 5^2 \cdot 17$ | 2,9294 |

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| $C = \pi \cdot d$ | $A = \frac{\pi \cdot d^2}{4}$ | $A = n^2$ | $V = n^3$ | Number $d$ or $n$ | $\sqrt{n}$ | $\sqrt[3]{n}$ | Factors and primes | lg $n$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 2 | 3 | | $\frac{1}{2}$ | $\frac{1}{3}$ | — | — |
| 2673,5 | 568786 | 724201 | 616295051 | 851 | 29,1719 | 9,4764 | $23 \cdot 37$ | 2,9299 |
| 2676,6 | 570124 | 725904 | 618470208 | 852 | 29,1890 | 9,4801 | $2^2 \cdot 3 \cdot 71$ | 2,9304 |
| 2679,8 | 571463 | 727609 | 620650477 | 853 | 29,2062 | 9,4838 | — | 2,9310 |
| 2682,9 | 572803 | 729316 | 622835864 | 854 | 29,2233 | 9,4875 | $2 \cdot 7 \cdot 61$ | 2,9315 |
| 2686,1 | 574146 | 731025 | 625026375 | 855 | 29,2404 | 9,4912 | $3^2 \cdot 5 \cdot 19$ | 2,9320 |
| 2689,2 | 575490 | 732736 | 627222016 | 856 | 29,2575 | 9,4949 | $2^3 \cdot 107$ | 2,9325 |
| 2692,3 | 576835 | 734449 | 629422793 | 857 | 29,2746 | 9,4986 | — | 2,9330 |
| 2695,5 | 578182 | 736164 | 631628712 | 858 | 29,2916 | 9,5023 | $2 \cdot 3 \cdot 11 \cdot 13$ | 2,9335 |
| 2698,6 | 579530 | 737881 | 633839779 | 859 | 29,3087 | 9,5060 | — | 2,9340 |
| 2701,8 | 580880 | 739600 | 636056000 | 860 | 29,3258 | 9,5097 | $2^2 \cdot 5 \cdot 43$ | 2,9345 |
| 2704,9 | 582232 | 741321 | 638277381 | 861 | 29,3428 | 9,5134 | $3 \cdot 7 \cdot 41$ | 2,9350 |
| 2708,1 | 583585 | 743044 | 640503928 | 862 | 29,3598 | 9,5171 | $2 \cdot 431$ | 2,9355 |
| 2711,2 | 584940 | 744769 | 642735647 | 863 | 29,3769 | 9,5207 | — | 2,9360 |
| 2714,3 | 586297 | 746496 | 644972544 | 864 | 29,3939 | 9,5244 | $2^5 \cdot 3^3$ | 2,9365 |
| 2717,5 | 587655 | 748225 | 647214625 | 865 | 29,4109 | 9,5281 | $5 \cdot 173$ | 2,9370 |
| 2720,6 | 589014 | 749956 | 649461896 | 866 | 29,4279 | 9,5317 | $2 \cdot 433$ | 2,9375 |
| 2723,8 | 590375 | 751689 | 651714363 | 867 | 29,4449 | 9,5354 | $3 \cdot 17^2$ | 2,9380 |
| 2726,9 | 591738 | 753424 | 653972032 | 868 | 29,4618 | 9,5391 | $2^2 \cdot 7 \cdot 31$ | 2,9385 |
| 2730,0 | 593102 | 755161 | 656234909 | 869 | 29,4788 | 9,5427 | $11 \cdot 79$ | 2,9390 |
| 2733,2 | 594468 | 756900 | 658503000 | 870 | 29,4958 | 9,5464 | $2 \cdot 3 \cdot 5 \cdot 29$ | 2,9395 |
| 2736,3 | 595835 | 758641 | 660776311 | 871 | 29,5127 | 9,5501 | $13 \cdot 67$ | 2,9400 |
| 2739,5 | 597204 | 760384 | 663054848 | 872 | 29,5296 | 9,5537 | $2^3 \cdot 109$ | 2,9405 |
| 2742,6 | 598575 | 762129 | 665338617 | 873 | 29,5466 | 9,5574 | $3^2 \cdot 97$ | 2,9410 |
| 2745,8 | 599947 | 763876 | 667627624 | 874 | 29,5635 | 9,5610 | $2 \cdot 19 \cdot 23$ | 2,9415 |
| 2748,9 | 601320 | 765625 | 669921875 | 875 | 29,5804 | 9,5647 | $5^3 \cdot 7$ | 2,9420 |
| 2752,0 | 602696 | 767376 | 672221376 | 876 | 29,5973 | 9,5683 | $2^2 \cdot 3 \cdot 73$ | 2,9425 |
| 2755,2 | 604073 | 769129 | 674526133 | 877 | 29,6142 | 9,5719 | — | 2,9430 |
| 2758,3 | 605451 | 770884 | 676836152 | 878 | 29,6311 | 9,5756 | $2 \cdot 439$ | 2,9435 |
| 2761,5 | 606831 | 772641 | 679151439 | 879 | 29,6479 | 9,5792 | $3 \cdot 293$ | 2,9440 |
| 2764,6 | 608212 | 774400 | 681472000 | 880 | 29,6648 | 9,5828 | $2^4 \cdot 5 \cdot 11$ | 2,9445 |
| 2767,7 | 609595 | 776161 | 683797841 | 881 | 29,6816 | 9,5865 | — | 2,9450 |
| 2770,9 | 610980 | 777924 | 686128968 | 882 | 29,6985 | 9,5901 | $2 \cdot 3^2 \cdot 7^2$ | 2,9455 |
| 2774,0 | 612366 | 779689 | 688465387 | 883 | 29,7153 | 9,5937 | — | 2,9460 |
| 2777,2 | 613754 | 781456 | 690807104 | 884 | 29,7321 | 9,5973 | $2^2 \cdot 13 \cdot 17$ | 2,9465 |
| 2780,3 | 615143 | 783225 | 693154125 | 885 | 29,7489 | 9,6010 | $3 \cdot 5 \cdot 59$ | 2,9469 |
| 2783,5 | 616534 | 784996 | 695506456 | 886 | 29,7658 | 9,6046 | $2 \cdot 443$ | 2,9474 |
| 2786,6 | 617927 | 786769 | 697864103 | 887 | 29,7825 | 9,6082 | — | 2,9479 |
| 2789,7 | 619321 | 788544 | 700227072 | 888 | 29,7993 | 9,6118 | $2^3 \cdot 3 \cdot 37$ | 2,9484 |
| 2792,9 | 620717 | 790321 | 702595369 | 889 | 29,8161 | 9,6154 | $7 \cdot 127$ | 2,9489 |
| 2796,0 | 622114 | 792100 | 704969000 | 890 | 29,8329 | 9,6190 | $2 \cdot 5 \cdot 89$ | 2,9494 |
| 2799,2 | 623513 | 793881 | 707347971 | 891 | 29,8496 | 9,6226 | $3^4 \cdot 11$ | 2,9499 |
| 2802,3 | 624913 | 795664 | 709732288 | 892 | 29,8664 | 9,6262 | $2^2 \cdot 223$ | 2,9504 |
| 2805,4 | 626315 | 797449 | 712121957 | 893 | 29,8831 | 9,6298 | $19 \cdot 47$ | 2,9509 |
| 2808,6 | 627718 | 799236 | 714516984 | 894 | 29,8998 | 9,6334 | $2 \cdot 3 \cdot 149$ | 2,9513 |
| 2811,7 | 629124 | 801025 | 716917375 | 895 | 29,9166 | 9,6370 | $5 \cdot 179$ | 2,9518 |
| 2814,9 | 630530 | 802816 | 719323136 | 896 | 29,9333 | 9,6406 | $2^7 \cdot 7$ | 2,9523 |
| 2818,0 | 631938 | 804609 | 721734273 | 897 | 29,9500 | 9,6442 | $3 \cdot 13 \cdot 23$ | 2,9528 |
| 2821,2 | 633348 | 806404 | 724150792 | 898 | 29,9666 | 9,6477 | $2 \cdot 449$ | 2,9533 |
| 2824,3 | 634760 | 808201 | 726572699 | 899 | 29,9833 | 9,6513 | $29 \cdot 31$ | 2,9538 |
| 2827,4 | 636173 | 810000 | 729000000 | 900 | 30,0000 | 9,6549 | $2^2 \cdot 3^2 \cdot 5^2$ | 2,9542 |

| $C = \pi \cdot d$ | $A = \frac{\pi \cdot d^2}{4}$ | $A = n^2$ | $V = n^3$ | Number $d$ or $n$ | $\sqrt{n}$ | $\sqrt[3]{n}$ | Factors and primes | lg $n$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 2 | 3 | | $\frac{1}{2}$ | $\frac{1}{3}$ | — | — |
| 2830,6 | 637587 | 811801 | 731432701 | 901 | 30,0167 | 9,6585 | $17 \cdot 53$ | 2,9547 |
| 2833,7 | 639003 | 813604 | 733870808 | 902 | 30,0333 | 9,6620 | $2 \cdot 11 \cdot 41$ | 2,9552 |
| 2836,9 | 640421 | 815409 | 736314327 | 903 | 30,0500 | 9,6656 | $3 \cdot 7 \cdot 43$ | 2,9557 |
| 2840,0 | 641840 | 817216 | 738763264 | 904 | 30,0666 | 9,6692 | $2^3 \cdot 113$ | 2,9562 |
| 2843,1 | 643261 | 819025 | 741217625 | 905 | 30,0832 | 9,6727 | $5 \cdot 181$ | 2,9567 |
| 2846,3 | 644683 | 820836 | 743677416 | 906 | 30,0998 | 9,6763 | $2 \cdot 3 \cdot 151$ | 2,9571 |
| 2849,4 | 646107 | 822649 | 746142643 | 907 | 30,1164 | 9,6799 | — | 2,9576 |
| 2852,6 | 647533 | 824464 | 748613312 | 908 | 30,1330 | 9,6834 | $2^2 \cdot 227$ | 2,9581 |
| 2855,7 | 648960 | 826281 | 751089429 | 909 | 30,1496 | 6,6870 | $3^2 \cdot 101$ | 2,9586 |
| 2858,8 | 650388 | 828100 | 753571000 | 910 | 30,1662 | 9,6905 | $2 \cdot 5 \cdot 7 \cdot 13$ | 2,9590 |
| 2862,0 | 651818 | 829921 | 756058031 | 911 | 30,1828 | 9,6941 | — | 2,9595 |
| 2865,1 | 653250 | 831744 | 758550528 | 912 | 30,1993 | 9,6976 | $2^4 \cdot 3 \cdot 19$ | 2,9600 |
| 2868,3 | 654684 | 833569 | 761048497 | 913 | 30,2159 | 9,7012 | $11 \cdot 83$ | 2,9605 |
| 2871,4 | 656118 | 835396 | 763551944 | 914 | 30,2324 | 9,7047 | $2 \cdot 457$ | 2,9610 |
| 2874,6 | 657555 | 837225 | 766060875 | 915 | 30,2490 | 9,7082 | $3 \cdot 5 \cdot 61$ | 2,9614 |
| 2877,7 | 658993 | 839056 | 768575296 | 916 | 30,2655 | 9,7118 | $2^2 \cdot 229$ | 2,9619 |
| 2880,8 | 660433 | 840889 | 771095213 | 917 | 30,2820 | 9,7153 | $7 \cdot 131$ | 2,9624 |
| 2884,0 | 661874 | 842724 | 773620632 | 918 | 30,2985 | 9,7188 | $2 \cdot 3^2 \cdot 17$ | 2,9628 |
| 2887,1 | 663317 | 844561 | 776151559 | 919 | 30,3150 | 9,7224 | — | 2,9633 |
| 2890,3 | 664761 | 846400 | 778688000 | 920 | 30,3315 | 9,7259 | $2^3 \cdot 5 \cdot 23$ | 2,9638 |
| 2893,4 | 666207 | 848241 | 781229961 | 921 | 30,3480 | 9,7294 | $3 \cdot 307$ | 2,9643 |
| 2896,5 | 667654 | 850084 | 783777448 | 922 | 30,3645 | 9,7329 | $2 \cdot 461$ | 2,9647 |
| 2899,7 | 669103 | 851929 | 786330467 | 923 | 30,3809 | 9,7364 | $13 \cdot 71$ | 2,9652 |
| 2902,8 | 670554 | 853776 | 788889024 | 924 | 30,3974 | 9,7400 | $2^2 \cdot 3 \cdot 7 \cdot 11$ | 2,9657 |
| 2906,0 | 672006 | 855625 | 791453125 | 925 | 30,4138 | 9,7435 | $5^2 \cdot 37$ | 2,9661 |
| 2909,1 | 673460 | 857476 | 794022776 | 926 | 30,4302 | 9,7470 | $2 \cdot 463$ | 2,9666 |
| 2912,3 | 674915 | 859329 | 796597983 | 927 | 30,4467 | 9,7505 | $3^2 \cdot 103$ | 2,9671 |
| 2915,4 | 676372 | 861184 | 799178752 | 928 | 30,4631 | 9,7540 | $2^5 \cdot 29$ | 2,9676 |
| 2918,5 | 677831 | 863041 | 801765089 | 929 | 30,4795 | 9,7575 | — | 2,9680 |
| 2921,7 | 679291 | 864900 | 804357000 | 930 | 30,4959 | 9,7610 | $2 \cdot 3 \cdot 5 \cdot 31$ | 2,9685 |
| 2924,8 | 680752 | 866761 | 806954491 | 931 | 30,5123 | 9,7645 | $7^2 \cdot 19$ | 2,9690 |
| 2928,0 | 672216 | 868624 | 809557568 | 932 | 30,5287 | 9,7680 | $2^2 \cdot 233$ | 2,9694 |
| 2931,1 | 683680 | 870489 | 812166237 | 933 | 30,5450 | 9,7715 | $3 \cdot 311$ | 2,9699 |
| 2934,2 | 685147 | 872356 | 814780504 | 934 | 30,5614 | 9,7750 | $2 \cdot 467$ | 2,9704 |
| 2937,4 | 686615 | 874225 | 817400375 | 935 | 30,5778 | 9,7785 | $5 \cdot 11 \cdot 17$ | 2,9708 |
| 2940,5 | 688084 | 876096 | 820025856 | 936 | 30,5941 | 9,7819 | $2^3 \cdot 3^2 \cdot 13$ | 2,9713 |
| 2943,7 | 689555 | 877969 | 822656953 | 937 | 30,6105 | 9,7854 | — | 2,9717 |
| 2946,8 | 691028 | 879844 | 825293672 | 938 | 30,6268 | 9,7889 | $2 \cdot 7 \cdot 67$ | 2,9722 |
| 2950,0 | 692502 | 881721 | 827936019 | 939 | 30,6431 | 9,7924 | $3 \cdot 313$ | 2,9727 |
| 2953,1 | 693978 | 883600 | 830584000 | 940 | 30,6594 | 9,7959 | $2^2 \cdot 5 \cdot 47$ | 2,9731 |
| 2956,2 | 695455 | 885481 | 833237621 | 941 | 30,6757 | 9,7993 | — | 2,9736 |
| 2959,4 | 696934 | 887364 | 835896888 | 942 | 30,6920 | 9,8028 | $2 \cdot 3 \cdot 157$ | 2,9741 |
| 2962,5 | 698415 | 889249 | 838561807 | 943 | 30,7083 | 9,8063 | $23 \cdot 41$ | 2,9745 |
| 2965,7 | 699897 | 891136 | 841232384 | 944 | 30,7246 | 9,8097 | $2^4 \cdot 59$ | 2,9750 |
| 2968,8 | 701380 | 893025 | 843908625 | 945 | 30,7409 | 9,8132 | $3^3 \cdot 5 \cdot 7$ | 2,9754 |
| 2971,9 | 702865 | 894916 | 846590536 | 946 | 30,7571 | 9,8167 | $2 \cdot 11 \cdot 43$ | 2,9759 |
| 2975,1 | 704352 | 896809 | 849278123 | 947 | 30,7734 | 9,8201 | — | 2,9764 |
| 2978,2 | 705840 | 898704 | 851971392 | 948 | 30,7896 | 9,8236 | $2^2 \cdot 3 \cdot 79$ | 2,9768 |
| 2981,4 | 707330 | 900601 | 854670349 | 949 | 30,8058 | 9,8270 | $13 \cdot 73$ | 2,9773 |
| 2984,5 | 708822 | 902500 | 857375000 | 950 | 30,8221 | 9,8305 | $2 \cdot 5^2 \cdot 19$ | 2,9777 |

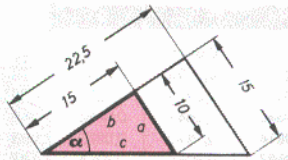
901 ... 950

951 ... 1000

| $C = \pi \cdot d$ | $A = \frac{\pi \cdot d^2}{4}$ | $A = n^2$ | $V = n^3$ | Number $d$ or $n$ | $\sqrt{n}$ | $\sqrt[3]{n}$ | Factors and primes | lg $n$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 2 | 3 | | $\frac{1}{2}$ | $\frac{1}{3}$ | — | — |
| 2987,7 | 710315 | 904401 | 860085351 | 951 | 30,8383 | 9,8339 | $3 \cdot 317$ | 2,9782 |
| 2990,8 | 711809 | 906304 | 862801408 | 952 | 30,8545 | 9,8374 | $2^3 \cdot 7 \cdot 17$ | 2,9786 |
| 2993,9 | 713306 | 908209 | 865523177 | 953 | 30,8707 | 9,8408 | — | 2,9791 |
| 2997,1 | 714803 | 910116 | 868250664 | 954 | 30,8869 | 9,8443 | $2 \cdot 3^2 \cdot 53$ | 2,9796 |
| 3000,2 | 716303 | 912025 | 870983875 | 955 | 30,9031 | 9,8477 | $5 \cdot 191$ | 2,9800 |
| 3003,4 | 717804 | 913936 | 873722816 | 956 | 30,9192 | 9,8511 | $2^2 \cdot 239$ | 2,9805 |
| 3006,5 | 719306 | 915849 | 876467493 | 957 | 30,9354 | 9,8546 | $3 \cdot 11 \cdot 29$ | 2,9809 |
| 3009,6 | 720810 | 917764 | 879217912 | 958 | 30,9516 | 9,8580 | $2 \cdot 479$ | 2,9814 |
| 3012,8 | 722316 | 919681 | 881974079 | 959 | 30,9677 | 9,8614 | $7 \cdot 137$ | 2,9818 |
| 3015,9 | 723823 | 921600 | 884736000 | 960 | 30,9839 | 9,8648 | $2^6 \cdot 3 \cdot 5$ | 2,9823 |
| 3019,1 | 725332 | 923521 | 887503681 | 961 | 31,0000 | 9,8683 | $31^2$ | 2,9827 |
| 3022,2 | 726842 | 925444 | 890277128 | 962 | 31,0161 | 9,8717 | $2 \cdot 13 \cdot 37$ | 2,9832 |
| 3025,4 | 728354 | 927369 | 893056347 | 963 | 31,0322 | 9,8751 | $3^2 \cdot 107$ | 2,9836 |
| 3028,5 | 729867 | 929296 | 895841344 | 964 | 31,0483 | 9,8785 | $2^2 \cdot 241$ | 2,9841 |
| 3031,6 | 731382 | 931225 | 898632125 | 965 | 31,0644 | 9,8819 | $5 \cdot 193$ | 2,9845 |
| 3034,8 | 732899 | 933156 | 901428696 | 966 | 31,0805 | 9,8854 | $2 \cdot 3 \cdot 7 \cdot 23$ | 2,9850 |
| 3037,9 | 734417 | 935089 | 904231063 | 967 | 31,0966 | 9,8888 | — | 2,9854 |
| 3041,1 | 735937 | 937024 | 907039232 | 968 | 31,1127 | 9,8922 | $2^3 \cdot 11^2$ | 2,9859 |
| 3044,2 | 737458 | 938961 | 909853209 | 969 | 31,1288 | 9,8956 | $3 \cdot 17 \cdot 19$ | 2,9863 |
| 3047,3 | 738981 | 940900 | 912673000 | 970 | 31,1448 | 9,8990 | $2 \cdot 5 \cdot 97$ | 2,9868 |
| 3050,5 | 740506 | 942841 | 915498611 | 971 | 31,1609 | 9,9024 | — | 2,9872 |
| 3053,6 | 742032 | 944784 | 918330048 | 972 | 31,1769 | 9,9058 | $2^2 \cdot 3^5$ | 2,9877 |
| 3056,8 | 743559 | 946729 | 921167317 | 973 | 31,1929 | 9,9092 | $7 \cdot 139$ | 2,9881 |
| 3059,9 | 745088 | 948676 | 924010424 | 974 | 31,2090 | 9,9126 | $2 \cdot 487$ | 2,9886 |
| 3063,1 | 746619 | 950625 | 926859375 | 975 | 31,2250 | 9,9160 | $3 \cdot 5^3 \cdot 13$ | 2,9890 |
| 3066,2 | 748151 | 952576 | 929714176 | 976 | 31,2410 | 9,9194 | $2^4 \cdot 61$ | 2,9895 |
| 3069,3 | 749685 | 954529 | 932574833 | 977 | 31,2570 | 9,9227 | — | 2,9899 |
| 3072,5 | 751221 | 956484 | 935441352 | 978 | 31,2730 | 9,9261 | $2 \cdot 3 \cdot 163$ | 2,9903 |
| 3075,6 | 752758 | 958441 | 938313739 | 979 | 31,2890 | 9,9295 | $11 \cdot 89$ | 2,9908 |
| 3078,8 | 754296 | 960400 | 941192000 | 980 | 31,3050 | 9,9329 | $2^2 \cdot 5 \cdot 7^2$ | 2,9912 |
| 3081,9 | 755837 | 962361 | 944076141 | 981 | 31,3209 | 9,9363 | $3^2 \cdot 109$ | 2,9917 |
| 3085,0 | 757378 | 964324 | 946966168 | 982 | 31,3369 | 9,9396 | $2 \cdot 491$ | 2,9921 |
| 3088,2 | 758922 | 966289 | 949862087 | 983 | 31,3528 | 9,9430 | — | 2,9926 |
| 3091,3 | 760466 | 968256 | 952763904 | 984 | 31,3688 | 9,9464 | $2^3 \cdot 3 \cdot 41$ | 2,9930 |
| 3094,5 | 762013 | 970225 | 955671625 | 985 | 31,3847 | 9,9497 | $5 \cdot 197$ | 2,9934 |
| 3097,6 | 763561 | 972196 | 958585256 | 986 | 31,4006 | 9,9531 | $2 \cdot 17 \cdot 29$ | 2,9939 |
| 3100,8 | 765111 | 974169 | 961504803 | 987 | 31,4166 | 9,9565 | $3 \cdot 7 \cdot 47$ | 2,9943 |
| 3103,9 | 766662 | 976144 | 964430272 | 988 | 31,4325 | 9,9598 | $2^2 \cdot 13 \cdot 19$ | 2,9948 |
| 3107,0 | 768214 | 978121 | 967361669 | 989 | 31,4484 | 9,9632 | $23 \cdot 43$ | 2,9952 |
| 3110,2 | 769769 | 980100 | 970299000 | 990 | 31,4643 | 9,9666 | $2 \cdot 3^2 \cdot 5 \cdot 11$ | 2,9956 |
| 3113,3 | 771325 | 982081 | 973242271 | 991 | 31,4802 | 9,9699 | — | 2,9961 |
| 3116,5 | 772882 | 984064 | 976191488 | 992 | 31,4960 | 9,9733 | $2^5 \cdot 31$ | 2,9965 |
| 3119,6 | 774441 | 986049 | 979146657 | 993 | 31,5119 | 9,9766 | $3 \cdot 331$ | 2,9970 |
| 3122,7 | 776002 | 988036 | 982107784 | 994 | 31,5278 | 9,9800 | $2 \cdot 7 \cdot 71$ | 2,9974 |
| 3125,9 | 777564 | 990025 | 985074875 | 995 | 31,5436 | 9,9833 | $5 \cdot 199$ | 2,9978 |
| 3129,0 | 779128 | 992016 | 988047936 | 996 | 31,5595 | 9,9866 | $2^2 \cdot 3 \cdot 83$ | 2,9983 |
| 3132,2 | 780693 | 994009 | 991026973 | 997 | 31,5753 | 9,9900 | — | 2,9987 |
| 3135,3 | 782260 | 996004 | 994011992 | 998 | 31,5911 | 9,9933 | $2 \cdot 499$ | 2,9991 |
| 3138,5 | 783828 | 998001 | 997002999 | 999 | 31,6070 | 9,9967 | $3^3 \cdot 37$ | 2,9996 |
| 3141,6 | 785398 | 1000000 | 1000000000 | 1000 | 31,6228 | 10,0000 | $2^3 \cdot 5^3$ | 3,0000 |

# Trigonometric tables

## Use of trigonometric tables



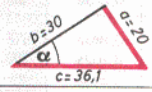

In a right-angled triangle the sides ratio $a : b$ has always the same value for the same angle $\alpha$

e.g.

$\alpha = 33° 40'$ $\quad \frac{a}{b} = \frac{10}{15} = 0.666 \quad \frac{a}{b} = \frac{15}{22.5} = 0.666$

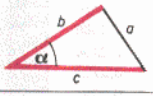
The same applies for the ratios $b : a$, $a : c$ and $b : c$.
The ratios determine the angle and vice versa.

System of naming the elements in right angled triangles: The side $c$ of a right angled triangle opposite the right angle is called the hypotenuse. The sides $a$, $b$ including the right angle are called the adjacent sides (the catheti or the smaller sides of rectangular triangles).



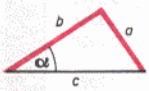

$\sin \alpha = \frac{a}{c}$

$\frac{a}{c} = \frac{20}{36.1} = 0.554$ corresponds to an angle $\alpha = 33° 40'$




$\cos \alpha = \frac{b}{c}$

$\frac{b}{c} = \frac{30}{36.1} = 0.831$ corresponds to an angle $\alpha = 33° 40'$




$\tan \alpha = \frac{a}{b}$

$\frac{a}{b} = \frac{20}{30} = 0.666$ corresponds to an angle $\alpha = 33° 40'$

$\cot \alpha = \frac{b}{a}$

$\frac{b}{a} = \frac{30}{20}$ 1.500 corresponds to an angle $\alpha = 33° 40'$

## Reading angle magnitudes from tables – The tables list angles in 10' incremental steps

Examples: $\alpha = 27° 14'$ $\quad \sin \alpha = ?$

$\sin 27° 20' = 0.4592$ | values taken
$\sin 27° 10' = 0.4566$ | from tables

Difference of $10' = 0.0026$

Difference of $1' = 0.00026$

$4' = 0.0010$
$\sin 27° 10' = 0.4566$
$\sin 27° 14' = 0.4576$

$0.5147 = \tan \alpha \quad \alpha = ?$

Difference 0.0015

$0.5169 = \tan 27° 20'$ | values taken
$0.5132 = \tan 27° 10'$ | from tables

Difference of $0.0037 = 10'$

Difference of $0.0001 = \frac{10'}{37}$

$0.0015 = \frac{15 \cdot 10}{37} = 4'$

$0.5132 = \tan 27° 10'$
$0.5147 = \tan 27° 14'$

Examples: $\alpha = 27° 14'$ $\quad \cos \alpha = ?$

$\cos 27° 10' = 0.8897$ | values taken
$\cos 27° 20' = 0.8884$ | from tables

Difference of $10' = 0.0013$

Difference of $1' = 0.00013$

$4' = 0.0005$
$\cos 27° 10' = 0.8897$
$\cos 27° 14' = 0.8892$

$1.9430 = \cot \alpha \quad \alpha = ?$

Difference 0.0056

$1.9486 = \cot 27° 10'$ | values taken
$1.9347 = \cot 27° 20'$ | from tables

Difference of $0.0139 = 10'$

Difference of $0.0001 = \frac{10'}{139}$

$0.0056 = \frac{56 \cdot 10}{139} = 4'$

$1.9486 = \cot 27° 10'$
$1.9430 = \cot 27° 14'$

## Formulae for the oblique triangle

Theorem of the sines: $\frac{a}{\sin \alpha} = \frac{b}{\sin \beta} = \frac{c}{\sin \gamma}$

Theorem of the cosines
$a^2 = b^2 + c^2 - 2\,bc \cos \alpha$
$b^2 = a^2 + c^2 - 2\,ac \cos \beta$
$c^2 = a^2 + b^2 - 2\,ab \cos \gamma$

Theorem of the tangent $\frac{\tan \frac{\alpha - \beta}{2}}{\tan \frac{\alpha + \beta}{2}} = \frac{a - b}{a + b}$

Area $A$ of a triangle $A = \frac{1}{2} ab \sin \gamma = \frac{1}{2} bc \sin \alpha = \frac{1}{2} ac \sin \beta$

## Sines 0...45°

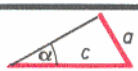
$\sin \alpha = \frac{a}{c}$; $a = c \cdot \sin \alpha$; $c = \frac{a}{\sin \alpha}$

| Degree | Minutes 0′ | 10′ | 20′ | 30′ | 40′ | 50′ | 60′ | |
|---|---|---|---|---|---|---|---|---|
| 0 | 0,0000 | 0,0029 | 0,0058 | 0,0087 | 0,0116 | 0,0145 | 0,0175 | 89 |
| 1 | 0,0175 | 0,0204 | 0,0233 | 0,0262 | 0,0291 | 0,0320 | 0,0349 | 88 |
| 2 | 0,0349 | 0,0378 | 0,0407 | 0,0436 | 0,0465 | 0,0494 | 0,0523 | 87 |
| 3 | 0,0523 | 0,0552 | 0,0581 | 0,0610 | 0,0640 | 0,0669 | 0,0698 | 86 |
| 4 | 0,0698 | 0,0727 | 0,0756 | 0,0785 | 0,0814 | 0,0843 | 0,0872 | 85 |
| 5 | 0,0872 | 0,0901 | 0,0929 | 0,0958 | 0,0987 | 0,1016 | 0,1045 | 84 |
| 6 | 0,1045 | 0,1074 | 0,1103 | 0,1132 | 0,1161 | 0,1190 | 0,1219 | 83 |
| 7 | 0,1219 | 0,1248 | 0,1276 | 0,1305 | 0,1334 | 0,1363 | 0,1392 | 82 |
| 8 | 0,1392 | 0,1421 | 0,1449 | 0,1478 | 0,1507 | 0,1536 | 0,1564 | 81 |
| 9 | 0,1564 | 0,1593 | 0,1622 | 0,1650 | 0,1679 | 0,1708 | 0,1736 | 80 |
| 10 | 0,1736 | 0,1765 | 0,1794 | 0,1822 | 0,1851 | 0,1880 | 0,1908 | 79 |
| 11 | 0,1908 | 0,1937 | 0,1965 | 0,1994 | 0,2022 | 0,2051 | 0,2079 | 78 |
| 12 | 0,2079 | 0,2108 | 0,2136 | 0,2164 | 0,2193 | 0,2221 | 0,2250 | 77 |
| 13 | 0,2250 | 0,2278 | 0,2306 | 0,2334 | 0,2363 | 0,2391 | 0,2419 | 76 |
| 14 | 0,2419 | 0,2447 | 0,2476 | 0,2504 | 0,2532 | 0,2560 | 0,2588 | 75 |
| 15 | 0,2588 | 0,2616 | 0,2644 | 0,2672 | 0,2700 | 0,2728 | 0,2756 | 74 |
| 16 | 0,2756 | 0,2784 | 0,2812 | 0,2840 | 0,2868 | 0,2896 | 0,2924 | 73 |
| 17 | 0,2924 | 0,2952 | 0,2979 | 0,3007 | 0,3035 | 0,3062 | 0,3090 | 72 |
| 18 | 0,3090 | 0,3118 | 0,3145 | 0,3173 | 0,3201 | 0,3228 | 0,3256 | 71 |
| 19 | 0,3256 | 0,3283 | 0,3311 | 0,3338 | 0,3365 | 0,3393 | 0,3420 | 70 |
| 20 | 0,3420 | 0,3448 | 0,3475 | 0,3502 | 0,3529 | 0,3557 | 0,3584 | 69 |
| 21 | 0,3584 | 0,3611 | 0,3638 | 0,3665 | 0,3692 | 0,3719 | 0,3746 | 68 |
| 22 | 0,3746 | 0,3773 | 0,3800 | 0,3827 | 0,3854 | 0,3881 | 0,3907 | 67 |
| 23 | 0,3907 | 0,3934 | 0,3961 | 0,3987 | 0,4014 | 0,4041 | 0,4067 | 66 |
| 24 | 0,4067 | 0,4094 | 0,4120 | 0,4147 | 0,4173 | 0,4200 | 0,4226 | 65 |
| 25 | 0,4226 | 0,4253 | 0,4279 | 0,4305 | 0,4331 | 0,4358 | 0,4384 | 64 |
| 26 | 0,4384 | 0,4410 | 0,4436 | 0,4462 | 0,4488 | 0,4514 | 0,4540 | 63 |
| 27 | 0,4540 | 0,4566 | 0,4592 | 0,4617 | 0,4643 | 0,4669 | 0,4695 | 62 |
| 28 | 0,4695 | 0,4720 | 0,4746 | 0,4772 | 0,4797 | 0,4823 | 0,4848 | 61 |
| 29 | 0,4848 | 0,4874 | 0,4899 | 0,4924 | 0,4950 | 0,4975 | 0,5000 | 60 |
| 30 | 0,5000 | 0,5025 | 0,5050 | 0,5075 | 0,5100 | 0,5125 | 0,5150 | 59 |
| 31 | 0,5150 | 0,5175 | 0,5200 | 0,5225 | 0,5250 | 0,5275 | 0,5299 | 58 |
| 32 | 0,5299 | 0,5324 | 0,5348 | 0,5373 | 0,5398 | 0,5422 | 0,5446 | 57 |
| 33 | 0,5446 | 0,5471 | 0,5495 | 0,5519 | 0,5544 | 0,5568 | 0,5592 | 56 |
| 34 | 0,5592 | 0,5616 | 0,5640 | 0,5664 | 0,5688 | 0,5712 | 0,5736 | 55 |
| 35 | 0,5736 | 0,5760 | 0,5783 | 0,5807 | 0,5831 | 0,5854 | 0,5878 | 54 |
| 36 | 0,5878 | 0,5901 | 0,5925 | 0,5948 | 0,5972 | 0,5995 | 0,6018 | 53 |
| 37 | 0,6018 | 0,6041 | 0,6065 | 0,6088 | 0,6111 | 0,6134 | 0,6157 | 52 |
| 38 | 0,6157 | 0,6180 | 0,6202 | 0,6225 | 0,6248 | 0,6271 | 0,6293 | 51 |
| 39 | 0,6293 | 0,6316 | 0,6338 | 0,6361 | 0,6383 | 0,6406 | 0,6428 | 50 |
| 40 | 0,6428 | 0,6450 | 0,6472 | 0,6494 | 0,6517 | 0,6539 | 0,6561 | 49 |
| 41 | 0,6561 | 0,6583 | 0,6604 | 0,6626 | 0,6648 | 0,6670 | 0,6691 | 48 |
| 42 | 0,6691 | 0,6713 | 0,6734 | 0,6756 | 0,6777 | 0,6799 | 0,6820 | 47 |
| 43 | 0,6820 | 0,6841 | 0,6862 | 0,6884 | 0,6905 | 0,6926 | 0,6947 | 46 |
| 44 | 0,6947 | 0,6967 | 0,6988 | 0,7009 | 0,7030 | 0,7050 | 0,7071 | 45 |
| | 60′ | 50′ | 40′ | 30′ | 20′ | 10′ | 0′ | Degree |
| | Minutes | | | | | | | |

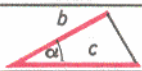
$\cos \alpha = \frac{b}{c}$; $b = c \cdot \cos \alpha$; $c = \frac{b}{\cos \alpha}$

## Cosines 45...90°

## Sines 45...90°




| Degree | Minutes 0′ | 10′ | 20′ | 30′ | 40′ | 50′ | 60′ | Degree |
|---|---|---|---|---|---|---|---|---|
| 45 | 0,7071 | 0,7092 | 0,7112 | 0,7133 | 0,7153 | 0,7173 | 0,7193 | 44 |
| 46 | 0,7193 | 0,7214 | 0,7234 | 0,7254 | 0,7274 | 0,7294 | 0,7314 | 43 |
| 47 | 0,7314 | 0,7333 | 0,7353 | 0,7373 | 0,7392 | 0,7412 | 0,7431 | 42 |
| 48 | 0,7431 | 0,7451 | 0,7470 | 0,7490 | 0,7509 | 0,7528 | 0,7547 | 41 |
| 49 | 0,7547 | 0,7566 | 0,7585 | 0,7604 | 0,7623 | 0,7642 | 0,7660 | 40 |
| 50 | 0,7660 | 0,7679 | 0,7698 | 0,7716 | 0,7735 | 0,7753 | 0,7771 | 39 |
| 51 | 0,7771 | 0,7790 | 0,7808 | 0,7826 | 0,7844 | 0,7862 | 0,7880 | 38 |
| 52 | 0,7880 | 0,7898 | 0,7916 | 0,7934 | 0,7951 | 0,7969 | 0,7986 | 37 |
| 53 | 0,7986 | 0,8004 | 0,8021 | 0,8039 | 0,8056 | 0,8073 | 0,8090 | 36 |
| 54 | 0,8090 | 0,8107 | 0,8124 | 0,8141 | 0,8158 | 0,8175 | 0,8192 | 35 |
| 55 | 0,8192 | 0,8208 | 0,8225 | 0,8241 | 0,8258 | 0,8274 | 0,8290 | 34 |
| 56 | 0,8290 | 0,8307 | 0,8323 | 0,8339 | 0,8355 | 0,8371 | 0,8387 | 33 |
| 57 | 0,8387 | 0,8403 | 0,8418 | 0,8434 | 0,8450 | 0,8465 | 0,8480 | 32 |
| 58 | 0,8480 | 0,8496 | 0,8511 | 0,8526 | 0,8542 | 0,8557 | 0,8572 | 31 |
| 59 | 0,8572 | 0,8587 | 0,8601 | 0,8616 | 0,8631 | 0,8646 | 0,8660 | 30 |
| 60 | 0,8660 | 0,8675 | 0,8689 | 0,8704 | 0,8718 | 0,8732 | 0,8746 | 29 |
| 61 | 0,8746 | 0,8760 | 0,8774 | 0,8788 | 0,8802 | 0,8816 | 0,8829 | 28 |
| 62 | 0,8829 | 0,8843 | 0,8857 | 0,8870 | 0,8884 | 0,8897 | 0,8910 | 27 |
| 63 | 0,8910 | 0,8923 | 0,8936 | 0,8949 | 0,8962 | 0,8975 | 0,8988 | 26 |
| 64 | 0,8988 | 0,9001 | 0,9013 | 0,9026 | 0,9038 | 0,9051 | 0,9063 | 25 |
| 65 | 0,9063 | 0,9075 | 0,9088 | 0,9100 | 0,9112 | 0,9124 | 0,9135 | 24 |
| 66 | 0,9135 | 0,9147 | 0,9159 | 0,9171 | 0,9182 | 0,9194 | 0,9205 | 23 |
| 67 | 0,9205 | 0,9216 | 0,9228 | 0,9239 | 0,9250 | 0,9261 | 0,9272 | 22 |
| 68 | 0,9272 | 0,9283 | 0,9293 | 0,9304 | 0,9315 | 0,9325 | 0,9336 | 21 |
| 69 | 0,9336 | 0,9346 | 0,9356 | 0,9367 | 0,9377 | 0,9387 | 0,9397 | 20 |
| 70 | 0,9397 | 0,9407 | 0,9417 | 0,9426 | 0,9436 | 0,9446 | 0,9455 | 19 |
| 71 | 0,9455 | 0,9465 | 0,9474 | 0,9483 | 0,9492 | 0,9502 | 0,9511 | 18 |
| 72 | 0,9511 | 0,9520 | 0,9528 | 0,9537 | 0,9546 | 0,9555 | 0,9563 | 17 |
| 73 | 0,9563 | 0,9572 | 0,9580 | 0,9588 | 0,9596 | 0,9605 | 0,9613 | 16 |
| 74 | 0,9613 | 0,9621 | 0,9628 | 0,9636 | 0,9644 | 0,9652 | 0,9659 | 15 |
| 75 | 0,9659 | 0,9667 | 0,9674 | 0,9681 | 0,9689 | 0,9696 | 0,9703 | 14 |
| 76 | 0,9703 | 0,9710 | 0,9717 | 0,9724 | 0,9730 | 0,9737 | 0,9744 | 13 |
| 77 | 0,9744 | 0,9750 | 0,9757 | 0,9763 | 0,9769 | 0,9775 | 0,9781 | 12 |
| 78 | 0,9781 | 0,9787 | 0,9793 | 0,9799 | 0,9805 | 0,9811 | 0,9816 | 11 |
| 79 | 0,9816 | 0,9822 | 0,9827 | 0,9833 | 0,9838 | 0,9843 | 0,9848 | 10 |
| 80 | 0,9848 | 0,9853 | 0,9858 | 0,9863 | 0,9868 | 0,9872 | 0,9877 | 9 |
| 81 | 0,9877 | 0,9881 | 0,9886 | 0,9890 | 0,9894 | 0,9899 | 0,9903 | 8 |
| 82 | 0,9903 | 0,9907 | 0,9911 | 0,9914 | 0,9918 | 0,9922 | 0,9925 | 7 |
| 83 | 0,9925 | 0,9929 | 0,9932 | 0,9936 | 0,9939 | 0,9942 | 0,9945 | 6 |
| 84 | 0,9945 | 0,9948 | 0,9951 | 0,9954 | 0,9957 | 0,9959 | 0,9962 | 5 |
| 85 | 0,9962 | 0,9964 | 0,9967 | 0,9969 | 0,9971 | 0,9974 | 0,9976 | 4 |
| 86 | 0,9976 | 0,9978 | 0,9980 | 0,9981 | 0,9983 | 0,9985 | 0,9986 | 3 |
| 87 | 0,9986 | 0,9988 | 0,9989 | 0,9990 | 0,9992 | 0,9993 | 0,9994 | 2 |
| 88 | 0,9994 | 0,9995 | 0,9996 | 0,9997 | 0,9997 | 0,9998 | 0,99985 | 1 |
| 89 | 0,99985 | 0,99989 | 0,99993 | 0,99996 | 0,99998 | 0,99999 | 1,0000 | 0 |
| | 60′ | 50′ | 40′ | 30′ | 20′ | 10′ | 0′ | Degree |
| | Minutes | | | | | | | |




## Cosines 0...45°

## Tangent 0...45°

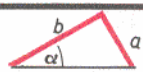
$\tan \alpha = \frac{a}{b}$; $a = b \cdot \tan \alpha$; $b = \frac{a}{\tan \alpha}$

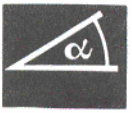
| Degree | Minutes 0′ | 10′ | 20′ | 30′ | 40′ | 50′ | 60′ | Degree |
|---|---|---|---|---|---|---|---|---|
| 0 | 0,0000 | 0,0029 | 0,0058 | 0,0087 | 0,0116 | 0,0145 | 0,0175 | 89 |
| 1 | 0,0175 | 0,0204 | 0,0233 | 0,0262 | 0,0291 | 0,0320 | 0,0349 | 88 |
| 2 | 0,0349 | 0,0378 | 0,0407 | 0,0437 | 0,0466 | 0,0495 | 0,0524 | 87 |
| 3 | 0,0524 | 0,0553 | 0,0582 | 0,0612 | 0,0641 | 0,0670 | 0,0699 | 86 |
| 4 | 0,0699 | 0,0729 | 0,0758 | 0,0787 | 0,0816 | 0,0846 | 0,0875 | 85 |
| 5 | 0,0875 | 0,0904 | 0,0934 | 0,0963 | 0,0992 | 0,1022 | 0,1051 | 84 |
| 6 | 0,1051 | 0,1080 | 0,1110 | 0,1139 | 0,1169 | 0,1198 | 0,1228 | 83 |
| 7 | 0,1228 | 0,1257 | 0,1287 | 0,1317 | 0,1346 | 0,1376 | 0,1405 | 82 |
| 8 | 0,1405 | 0,1435 | 0,1465 | 0,1495 | 0,1524 | 0,1554 | 0,1584 | 81 |
| 9 | 0,1584 | 0,1614 | 0,1644 | 0,1673 | 0,1703 | 0,1733 | 0,1763 | 80 |
| 10 | 0,1763 | 0,1793 | 0,1823 | 0,1853 | 0,1883 | 0,1914 | 0,1944 | 79 |
| 11 | 0,1944 | 0,1974 | 0,2004 | 0,2035 | 0,2065 | 0,2095 | 0,2126 | 78 |
| 12 | 0,2126 | 0,2156 | 0,2186 | 0,2217 | 0,2247 | 0,2278 | 0,2309 | 77 |
| 13 | 0,2309 | 0,2339 | 0,2370 | 0,2401 | 0,2432 | 0,2462 | 0,2493 | 76 |
| 14 | 0,2493 | 0,2524 | 0,2555 | 0,2586 | 0,2617 | 0,2648 | 0,2679 | 75 |
| 15 | 0,2679 | 0,2711 | 0,2742 | 0,2773 | 0,2805 | 0,2836 | 0,2867 | 74 |
| 16 | 0,2867 | 0,2899 | 0,2931 | 0,2962 | 0,2994 | 0,3026 | 0,3057 | 73 |
| 17 | 0,3057 | 0,3089 | 0,3121 | 0,3153 | 0,3185 | 0,3217 | 0,3249 | 72 |
| 18 | 0,3249 | 0,3281 | 0,3314 | 0,3346 | 0,3378 | 0,3411 | 0,3443 | 71 |
| 19 | 0,3443 | 0,3476 | 0,3508 | 0,3541 | 0,3574 | 0,3607 | 0,3640 | 70 |
| 20 | 0,3640 | 0,3673 | 0,3706 | 0,3739 | 0,3772 | 0,3805 | 0,3839 | 69 |
| 21 | 0,3839 | 0,3872 | 0,3906 | 0,3939 | 0,3973 | 0,4006 | 0,4040 | 68 |
| 22 | 0,4040 | 0,4074 | 0,4108 | 0,4142 | 0,4176 | 0,4210 | 0,4245 | 67 |
| 23 | 0,4245 | 0,4279 | 0,4314 | 0,4348 | 0,4383 | 0,4417 | 0,4452 | 66 |
| 24 | 0,4452 | 0,4487 | 0,4522 | 0,4557 | 0,4592 | 0,4628 | 0,4663 | 65 |
| 25 | 0,4663 | 0,4699 | 0,4734 | 0,4770 | 0,4806 | 0,4841 | 0,4877 | 64 |
| 26 | 0,4877 | 0,4913 | 0,4950 | 0,4986 | 0,5022 | 0,5059 | 0,5095 | 63 |
| 27 | 0,5095 | 0,5132 | 0,5169 | 0,5206 | 0,5243 | 0,5280 | 0,5317 | 62 |
| 28 | 0,5317 | 0,5354 | 0,5392 | 0,5430 | 0,5467 | 0,5505 | 0,5543 | 61 |
| 29 | 0,5543 | 0,5581 | 0,5619 | 0,5658 | 0,5696 | 0,5735 | 0,5774 | 60 |
| 30 | 0,5774 | 0,5812 | 0,5851 | 0,5890 | 0,5930 | 0,5969 | 0,6009 | 59 |
| 31 | 0,6009 | 0,6048 | 0,6088 | 0,6128 | 0,6168 | 0,6208 | 0,6249 | 58 |
| 32 | 0,6249 | 0,6289 | 0,6330 | 0,6371 | 0,6412 | 0,6453 | 0,6494 | 57 |
| 33 | 0,6494 | 0,6536 | 0,6577 | 0,6619 | 0,6661 | 0,6703 | 0,6745 | 56 |
| 34 | 0,6745 | 0,6787 | 0,6830 | 0,6873 | 0,6916 | 0,6959 | 0,7002 | 55 |
| 35 | 0,7002 | 0,7046 | 0,7089 | 0,7133 | 0,7177 | 0,7221 | 0,7265 | 54 |
| 36 | 0,7265 | 0,7310 | 0,7355 | 0,7400 | 0,7445 | 0,7490 | 0,7536 | 53 |
| 37 | 0,7536 | 0,7581 | 0,7627 | 0,7673 | 0,7720 | 0,7766 | 0,7813 | 52 |
| 38 | 0,7813 | 0,7860 | 0,7907 | 0,7954 | 0,8002 | 0,8050 | 0,8098 | 51 |
| 39 | 0,8098 | 0,8146 | 0,8195 | 0,8243 | 0,8292 | 0,8342 | 0,8391 | 50 |
| 40 | 0,8391 | 0,8441 | 0,8491 | 0,8541 | 0,8591 | 0,8642 | 0,8693 | 49 |
| 41 | 0,8693 | 0,8744 | 0,8796 | 0,8847 | 0,8899 | 0,8952 | 0,9004 | 48 |
| 42 | 0,9004 | 0,9057 | 0,9110 | 0,9163 | 0,9217 | 0,9271 | 0,9325 | 47 |
| 43 | 0,9325 | 0,9380 | 0,9435 | 0,9490 | 0,9545 | 0,9601 | 0,9657 | 46 |
| 44 | 0,9657 | 0,9713 | 0,9770 | 0,9827 | 0,9884 | 0,9942 | 1,0000 | 45 |
| | 60′ | 50′ | 40′ | 30′ | 20′ | 10′ | 0′ | Degree |
| | Minutes | | | | | | | |

$\cot \alpha = \frac{b}{a}$; $b = a \cdot \cot \alpha$; $a = \frac{b}{\cot \alpha}$

## Cotangent 45...90°

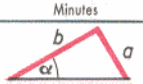
## Tangent 45 ... 90°




| Degree | Minutes 0′ | 10′ | 20′ | 30′ | 40′ | 50′ | 60′ | Degree |
|---|---|---|---|---|---|---|---|---|
| 45 | 1,0000 | 1,0058 | 1,0117 | 1,0176 | 1,0235 | 1,0295 | 1,0355 | 44 |
| 46 | 1,0355 | 1,0416 | 1,0477 | 1,0538 | 1,0599 | 1,0661 | 1,0724 | 43 |
| 47 | 1,0724 | 1,0786 | 1,0850 | 1,0913 | 1,0977 | 1,1041 | 1,1106 | 42 |
| 48 | 1,1106 | 1,1171 | 1,1237 | 1,1303 | 1,1369 | 1,1436 | 1,1504 | 41 |
| 49 | 1,1504 | 1,1571 | 1,1640 | 1,1708 | 1,1778 | 1,1847 | 1,1918 | 40 |
| 50 | 1,1918 | 1,1988 | 1,2059 | 1,2131 | 1,2203 | 1,2276 | 1,2349 | 39 |
| 51 | 1,2349 | 1,2423 | 1,2497 | 1,2572 | 1,2647 | 1,2723 | 1,2799 | 38 |
| 52 | 1,2799 | 1,2876 | 1,2954 | 1,3032 | 1,3111 | 1,3190 | 1,3270 | 37 |
| 53 | 1,3270 | 1,3351 | 1,3432 | 1,3514 | 1,3597 | 1,3680 | 1,3764 | 36 |
| 54 | 1,3764 | 1,3848 | 1,3934 | 1,4019 | 1,4106 | 1,4193 | 1,4281 | 35 |
| 55 | 1,4281 | 1,4370 | 1,4460 | 1,4550 | 1,4641 | 1,4733 | 1,4826 | 34 |
| 56 | 1,4826 | 1,4919 | 1,5013 | 1,5108 | 1,5204 | 1,5301 | 1,5399 | 33 |
| 57 | 1,5399 | 1,5497 | 1,5597 | 1,5697 | 1,5798 | 1,5900 | 1,6003 | 32 |
| 58 | 1,6003 | 1,6107 | 1,6213 | 1,6318 | 1,6426 | 1,6534 | 1,6643 | 31 |
| 59 | 1,6643 | 1,6753 | 1,6864 | 1,6977 | 1,7090 | 1,7205 | 1,7321 | 30 |
| 60 | 1,7321 | 1,7438 | 1,7556 | 1,7675 | 1,7796 | 1,7917 | 1,8041 | 29 |
| 61 | 1,8041 | 1,8165 | 1,8291 | 1,8418 | 1,8546 | 1,8676 | 1,8807 | 28 |
| 62 | 1,8807 | 1,8940 | 1,9074 | 1,9210 | 1,9347 | 1,9486 | 1,9626 | 27 |
| 63 | 1,9626 | 1,9768 | 1,9912 | 2,0057 | 2,0204 | 2,0353 | 2,0503 | 26 |
| 64 | 2,0503 | 2,0655 | 2,0809 | 2,0965 | 2,1123 | 2,1283 | 2,1445 | 25 |
| 65 | 2,1445 | 2,1609 | 2,1775 | 2,1943 | 2,2113 | 2,2286 | 2,2460 | 24 |
| 66 | 2,2460 | 2,2637 | 2,2817 | 2,2998 | 2,3183 | 2,3369 | 2,3559 | 23 |
| 67 | 2,3559 | 2,3750 | 2,3945 | 2,4142 | 2,4342 | 2,4545 | 2,4751 | 22 |
| 68 | 2,4751 | 2,4960 | 2,5172 | 2,5387 | 2,5605 | 2,5826 | 2,6051 | 21 |
| 69 | 2,6051 | 2,6279 | 2,6511 | 2,6746 | 2,6985 | 2,7228 | 2,7475 | 20 |
| 70 | 2,7475 | 2,7725 | 2,7980 | 2,8239 | 2,8502 | 2,8770 | 2,9042 | 19 |
| 71 | 2,9042 | 2,9319 | 2,9600 | 2,9887 | 3,0178 | 3,0475 | 3,0777 | 18 |
| 72 | 3,0777 | 3,1084 | 3,1397 | 3,1716 | 3,2041 | 3,2371 | 3,2709 | 17 |
| 73 | 3,2709 | 3,3052 | 3,3402 | 3,3759 | 3,4124 | 3,4495 | 3,4874 | 16 |
| 74 | 3,4874 | 3,5261 | 3,5656 | 3,6059 | 3,6470 | 3,6891 | 3,7321 | 15 |
| 75 | 3,7321 | 3,7760 | 3,8208 | 3,8667 | 3,9136 | 3,9617 | 4,0108 | 14 |
| 76 | 4,0108 | 4,0611 | 4,1126 | 4,1653 | 4,2193 | 4,2747 | 4,3315 | 13 |
| 77 | 4,3315 | 4,3897 | 4,4494 | 4,5107 | 4,5736 | 4,6383 | 4,7046 | 12 |
| 78 | 4,7046 | 4,7729 | 4,8430 | 4,9152 | 4,9894 | 5,0658 | 5,1446 | 11 |
| 79 | 5,1446 | 5,2257 | 5,3093 | 5,3955 | 5,4845 | 5,5764 | 5,6713 | 10 |
| 80 | 5,6713 | 5,7694 | 5,8708 | 5,9758 | 6,0844 | 6,1970 | 6,3138 | 9 |
| 81 | 6,3138 | 6,4348 | 6,5605 | 6,6912 | 6,8269 | 6,9682 | 7,1154 | 8 |
| 82 | 7,1154 | 7,2687 | 7,4287 | 7,5958 | 7,7704 | 7,9530 | 8,1444 | 7 |
| 83 | 8,1444 | 8,3450 | 8,5556 | 8,7769 | 9,0098 | 9,2553 | 9,5144 | 6 |
| 84 | 9,5144 | 9,7882 | 10,0780 | 10,3854 | 10,7019 | 11,0594 | 11,4301 | 5 |
| 85 | 11,4301 | 11,8262 | 12,2505 | 12,7062 | 13,1969 | 13,7267 | 14,3007 | 4 |
| 86 | 14,3007 | 14,9244 | 15,6048 | 16,3499 | 17,1693 | 18,0750 | 19,0811 | 3 |
| 87 | 19,0811 | 20,2056 | 21,4704 | 22,9038 | 24,5418 | 26,4316 | 28,6363 | 2 |
| 88 | 28,6363 | 31,2416 | 34,3678 | 38,1885 | 42,9641 | 49,1039 | 57,2900 | 1 |
| 89 | 57,2900 | 68,7501 | 85,9398 | 114,5887 | 171,885 | 343,774 | ∞ | 0 |
| | 60′ | 50′ | 40′ | 30′ | 20′ | 10′ | 0′ | Degree |

Minutes




## Cotangent 0...45°

# Units

DIN 1301 (Nov. 71)

## Names and symbols for units

The "Law of units in measuring techniques" – Federal Republic of Germany 2nd July 1969 lays down the use of units in the International Unit System (SI-units) in business and official communications.

### Coherent SI-units

| Basic | | Length | Mass [1] | Time | Strength of current | Temperature | Intensity of light | Quantity of material |
|---|---|---|---|---|---|---|---|---|
| Basic unit | Name | meter | kilogram | seconds | ampere | kelvin | candela | mol |
| | Symbol | **m** | **kg** | **s** | **A** | **K** | **cd** | **mol** |

[1] Mass = Weight as obtained on a physical balance (kg is the only SI-unit with a prefix). The units derived from the basic units having a number factor 1 together with the basic units constitute the basic system of the coherent SI-units (e.g. Basic unit length: m. SI-unit surface area 1 m. $1\ m = 1\ m^2$). All those units derived from the SI-units having a factor different from one are not SI-units (e.g. units with prefixes as partitions or multiples of SI-units or $1t = 1000\ kg$: or 1 min. = 60s)

DIN 5494

| SI-units | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Quantity | | Surface area | Mass per unit length | Number of revolutions per unit time (Rot. frequ.) | Voltage | Thermal capacity | Intensity of illumination | Molar mass |
| | Name | square meter | kilogram per meter | second inverse | Volts | Joules per Kelvin | Lux | kilogram per mole |
| | Symbol | $m^2$ | kg/m | 1/s | V | J/K | lx | kg/mol |
| Quantity | | Volume | Mass per unit area | Frequency | Electrical resistance | Thermal conductivity | Luminous flux | Molarity |
| | Name | cubic meter | kilogram per square meter | Hertz | Ohm | Watt per Kelvin | Lumen | mole per cubic meter |
| | Symbol | $m^3$ | $kg/m^2$ | Hz | Ω | W/(K m) | lm | $mol/m^3$ |
| Quantity | | Strain | Density | Speed | Electrical charge | Heat transfer coefficient | Luminous flux density | |
| | Name | meter per meter | kilogram per cubic meter | meters per second | Coulomb | Watt per Kelvin square meter | candela per square meter | |
| | Symbol | m/m | $kg/m^3$ | m/s | C | $W/Km^2$ | $cd/m^2$ | |
| Quantity | | Length inverse | Specific volume | Aceleration | Electrical capacity | Temperature conductivity | | |
| | Name | Meter inverse | cubic meter per kg | meter per square second | Farad | Square meter per second | | |
| | Symbol | 1/m | $m^3/kg$ | $m/s^2$ | F | $m^2/s$ | | |

## Coherent SI-units for angles, force, energy and power

| Quantity | SI-units Symbol | SI-units Name | Relation | Remarks |
|---|---|---|---|---|
| Plane angle | rad | radian | 1 rad = 1 m/m | DIN 1315: unit radian $\frac{\text{arc of a circle}}{\text{radius of circle}} = 1$; ($360° = 2\,\pi$ rad) |
| Force weight force | N | Newton | $1\,N = 1\,kg\,m/s^2$ | DIN 1305: the units of weight are the force units ($G = m \cdot g$) (force = mass · acceleration in due to gravity). |
| Pressure mechanical stress | $N/m^2$ | Newton per square meter | $1\,Nm^2 = 1\,kg\,m/s^2\,m^2$ | DIN 1314: magnitude of pressure = magnitude of normal force divided by the surface area ($p = F_n/A$) |
| | Pa | Pascal | $1\,Pa = 1\,N/m^2$ | |
| Work, energy, heat quantity | J | Joule | $1\,J = 1\,Nm$<br>$1\,J = 1\,kg\,m^2/s^2$<br>$1\,J = 1\,W\,s$ | DIN 1345: The SI-unit of the energy is the Joule |
| Power, energy flow, heat flow | W | | $1\,W = 1\,J/s$<br>$1\,W = 1\,Nm/s$ | Power = work, energy or heat per unit of time |
| Moment of force (Turning moment) (Bending moment) | Nm | Newton meter | $1\,Nm = 1\,J$ | Moment of force = Force times effective distance of the force |
| | J | Joule | $1\,J = 1\,Ws$ | |

## Non-coherent units

| | | | | |
|---|---|---|---|---|
| Volume | l | litre | $1\,l = 1\,dm^3$<br>$1\,l = 10^{-3}\,m^3$ | Further fractional parts or multiples |
| Mass | g | gram | $1\,g = 10^{-3}\,kg$ | DIN 1305: for a quantum of objects, the units of weight are the units of mass |
| | t | ton | $1\,t = 10^3\,kg$ | |
| Time | min | minute | $1\,min = 60\,s$ | 3 h is the time span (3 hrs): $3^h$ is the time instant (3 o' clock) |
| | h | hour | $1\,h = 60\,min$ | |
| | d | day | $1\,d = 24\,h$ | |
| Revolutions per minute | 1/min | reciprocal minute | $1/min = 1/(60\,s)$ | Do not say km 'per' hour but preferably km divided by an hour |
| Speed | km/h | kilometre per hour | $1\,km/h = \frac{1}{3{,}6}\,m/s$ | |
| Pressure (gases) (liquids) | bar | bar | $1\,bar = 10^5\,Pa$<br>$1\,bar = 10^5\,N/m^2$ | DIN 1314: under pressure $p_u$ = reference pressure — working pressure, over pressure $p_u$ = pressure minus reference pressure |
| Electric energy | kWh | kilowatt hour | $1\,kWh = 3{,}6\,MJ$ | |
| Quantum of electricity | Ah | Ampere hour | $1\,Ah = 3600\,As$ | |
| Temperature | °C | degrees centrigrade | $\Delta\,t = 100° - 50°C$<br>$\Delta\,t = 50°C$ | The deg. C is a special term for Kelvin for the data in Celsius temperatures |
| Plain angle | L | right angle | $1\,L = \pi/2$ rad | Decimals, multiples and fractions cannot be used for the angular units: right angle, degree, minute and second. |
| | ° | degrees | $1° = \pi/180$ rad | |
| | ' | minutes | $1' = 1°/60$ | |
| | " | seconds | $1'' = 1'/60$ | |

## Decimal parts and multiples of units[1)]

| Prefix | Micro | Milli | Centi | Deci | Deca | Hecto | Kilo | Mega |
|---|---|---|---|---|---|---|---|---|
| Symbol | $\mu$ | m | c | d | da | h | k | M |
| Power | $10^{-6}$ | $10^{-3}$ | $10^{-2}$ | $10^{-1}$ | 10 | $10^{2}$ | $10^{3}$ | $10^{6}$ |

[1)] Decimal parts and multiples of units are non-coherent units.

Note: The prefices (Micro-Mega) include numeral values between 0,1 and 1000.
Units with clear numerical values are often more appropriate as coherent units.

Notations of symbols for derived units.
In order to avoid mistakes, it would be advisable to write products of unit symbols with a clear gap and without the multiplications sign (e.g. N m instead of Nm or N.m)

For divisors in Quotients of unit symbols, both notations with a stroke and a negative exponent are equally correct.
(e.g. kg m/s$^2$; or kg m s$^{-2}$; or N/m$^2$ = N m$^{-2}$; or kg m s$^{-2}$ = kg m / s$^2$).

## Notations of equations

DIN 1313 (Sept. 62)

**Physical quantity:**
Measurable property of objects, status or phenomena (e.g. length, mass, time, speed)

**Physical unit:**
A quantity (e.g.m.) selected and determined from a collection of similar quantities (e.g. length) as reference quantity

**Numerical value of a quantity:**
The ratio of the quantity to the unit:
Quantity = numerical value x unit (e.g.: $l = 5$ m)

**Symbols for quantities:**
Are printed in italics (e.g. length $l$, time $t$, velocity $v$)

**Short forms for units:**
Are printed in upright writing (e.g.: Meter m, Second s, Kilogram kg)

**Equation of quantities:**
The formulae describe clearly the physical quantities (e.g.: $v = s/t$). By evaluating the equations, the quantities are determined by the products of numerical value and unit.
Numerical values and units are independent factors (e.g.: $v = 5$ m/s

**Unit equation:**
Consists only of units and numerical values and gives the numerical relation between units (e.g.. 1 m = 1000 mm). Generally, the numerical value on the left side of the equation is equal to 1

**Numerical value equation:**
The formulae clarify the numerical values (e.g. circumferential velocity $v = 3{,}14\, d \cdot n$) The details of the units can be tabulated in the following form.

e.g.

| $v$ | $d$ | $n$ |
|---|---|---|
| m/s | m | 1/min |

**Precise dimensional equation:**
An equation of quantities, where each quantity is divided by a corresponding unit, is called a precise dimensional equation.

e.g. $\frac{v}{\text{m/s}} = \frac{s/\text{m}}{t/\text{s}}$

## Old units, not to use any more

| Quantity | Old unit | | Legal units | | Conversion |
|---|---|---|---|---|---|
| | Symbol | Name | Symbol | Name | |
| Length | " | Inch | mm | Millimeter | 1" = 25.4 mm |
| Force | kp | Kilogram force | N | Newton | 1 kp = 9,80665 N |
| Pressure | at | technical atmosphere | bar | Bar | 1 at = 0.980665 bar |
| | atm | physical atmosphere | | | 1 atm = 1,01325 bar |
| | m WS | Meter-water-columns | | | 1 mm WS = 98.0665 mbar |
| | mm Hg | millimeter | | | |
| | mm QS | Mercury columns | | | 1 mm Hg = 1,33322 mbar |
| Quantum of heat | cal | calorie | J | Joule | 1 cal = 4.1868 J |
| Temperature-difference | deg<br>°K | Degree<br>Degree Kelvin | K | Kelvin | 1 grd = 1 K<br>1 °K = 1 K |
| Power | PS | Horse power | W | Watt | 1 PS = 735.498 W |
| Moment of force | kp m | kilogram force meter | N m | Newton meter | 1 kp m = 9.81 N m |
| Mechanical work | kp m | kilogram force meter | J | Joule | 1 kp m = 9.81 J |
| Mechanical stress | $kp/cm^2$ | kilogram force per square centimeter | $N/cm^2$ | Newton divided by square centimeter | 1 $kp/cm^2$ = 9.81 $N/cm^2$ |
| Strength | $kp/mm^2$ | per square millimeter | $N/mm^2$ | Newton divided by square millimeter | 1 $kp/mm^2$ = 9.81 N $mm^2$ |
| Coefficient of linear (thermal) expansion | $\frac{1}{deg}$ | | 1 K | 1 divided by Kelvin | 1/degree = $K^{-1}$ = 1 K |
| Specific heat | $\frac{kcal}{kg}$ | kilo-calories per kilogram | kJ/kg | Kilojoule divided by kilogram | 1 kcal/kg = 4,18 kJ/kg |
| Thermal conductivity | $\frac{kcal}{mh°C}$ | kilo-calorie per meter hour and degree C | W/Km | Watt divided by Kelvin meter | $1\ \frac{kcal}{m \cdot h \cdot °C} = 1.168\ \frac{W}{Km}$ |
| Calorific value | $\frac{kcal}{kg}$ | kilo-calorie per kilogram | kJ/kg | Kilojoule divided by kilogram | 1 kcal/kg = 4.18 kJ/kg |

## Inch–Millimeter (1 in = 25,4 mm)

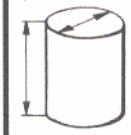
| in | 0 | 1/8 | 1/4 | 3/8 | 1/2 | 5/8 | 3/4 | 7/8 |
|---|---|---|---|---|---|---|---|---|
| 0 | | 3,18 | 6,35 | 9,53 | 12,70 | 15,88 | 19,05 | 22,23 |
| 1 | 25,40 | 28,58 | 31,75 | 34,93 | 38,10 | 41,28 | 44,45 | 47,63 |
| 2 | 50,80 | 53,97 | 57,15 | 60,33 | 63,50 | 66,68 | 69,85 | 73,03 |
| 3 | 76,20 | 79,38 | 82,55 | 85,73 | 88,90 | 92,08 | 95,25 | 98,43 |
| 4 | 101,60 | 104,78 | 107,95 | 111,13 | 114,30 | 117,48 | 120,65 | 123,83 |
| 5 | 127,00 | 130,18 | 133,35 | 136,53 | 139,70 | 142,88 | 146,05 | 149,23 |
| 6 | 152,40 | 155,58 | 158,75 | 161,93 | 165,10 | 168,28 | 171,45 | 174,63 |
| 7 | 177,80 | 180,98 | 184,15 | 187,33 | 190,50 | 193,68 | 196,85 | 200,03 |
| 8 | 203,20 | 206,38 | 209,55 | 212,73 | 215,90 | 219,08 | 222,25 | 225,43 |
| 9 | 228,60 | 231,78 | 234,95 | 238,13 | 241,30 | 244,48 | 247,65 | 250,83 |
| 10 | 254,00 | 257,18 | 260,35 | 263,53 | 266,70 | 269,88 | 273,05 | 276,23 |

## Greek alphabets

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $A$ $\alpha$ | a | Alpha | $Z$ $\zeta$ | z | Zeta | $\Lambda$ $\lambda$ | l | Lambda | $\Pi$ $\pi$ | p | Pi | $\Phi$ $\varphi$ | ph | Phi |
| $B$ $\beta$ | b | Beta | $H$ $\eta$ | e | Eta | $M$ $\mu$ | m | Mü | $P$ $\varrho$ | r | Rho | $X$ $\chi$ | ch | Chi |
| $\Gamma$ $\gamma$ | g | Gamma | $\Theta$ $\vartheta$ | th | Theta | $N$ $\nu$ | n | Nü | $\Sigma$ $\sigma$ | s | Sigma | $\Psi$ $\psi$ | ps | Psi |
| $\Delta$ $\delta$ | d | Delta | $I$ $\iota$ | i | Jota | $\Xi$ $\xi$ | x | Ksi | $T$ $\tau$ | t | Tau | $\Omega$ $\omega$ | o | Omega |
| $E$ $\varepsilon$ | e | Epsilon | $K$ $\varkappa$ | k | Kappa | $O$ $o$ | o | Omikron | $Y$ $\upsilon$ | ü | Ypsilon | | | |

## Symbols for physical quantities

DIN 1304 (Nov. 71)

| | Symbol | Physical quantity |
|---|---|---|
| Geometrical quantities  | $l\,(s)$ | Length |
| | $h$ | Height |
| | $b$ | Breadth |
| | $r, R$ | Radius |
| | $d, D$ | Diameter |
| | $A\,(S)$ | Area (cross section) |
| | $V$ | Occupied space, volume |
| | $\alpha, \beta, \gamma$ | Angle |
| Time | $t$ | Time (instant range or time) |
| | $n$ | Revolutions (frequ. of rotation) |
| | $v$ | Speed |
| | $\omega$ | Angular speed |
| | $a$ | Acceleration |
| | $g$ | Acceleration due to gravity |
| Temperature | $t, \vartheta$ | Celsius-temperature |
| | $T, \theta$ | Thermodynamic temperature |
| | $\alpha$ | Coefficient of linear (thermal) expansion |
| | $\gamma\ \beta$ | Coefficient of volumetric (thermal) expansion |

| | Symbol | Physical quantity |
|---|---|---|
| Force Pressure Mass | $F$ | Force |
| | $G$ | Weight force |
| | $m$ | Mass |
| | $\varrho$ | Density |
| | $M, T$ | Moment of a force (force x leverage) |
| | $p$ | Pressure (force/area) |
| | $\sigma$ | Compressive or tensile strength |
| | $\tau$ | Shear stress, torsional stress |
| | $E$ | Modulus of elasticity |
| | $\varepsilon$ | Strain |
| | $\mu$ | Coefficient of friction |
| Heat, Work, Energy | $W, A$ | Work |
| | $P$ | Power |
| | $W, E$ | Energy |
| | $\eta$ | Efficiency |
| | $Q$ | Quantum of heat |
| | $c$ | Specific heat |
| | $\lambda$ | Thermal conductivity |
| Electrical quantities | $U$ | Electric voltage |
| | $I$ | Electric current |
| | $R$ | Electric resistance |
| | $\varrho$ | Specific electric resistance |
| | $\varkappa, \gamma$ | Electrical conductivity |
| | $Q$ | Quantum of electricity |

## Mathematical signs

DIN 1302 (Feb. 68)

| Symbol | Enunciation |
|---|---|
| 1. | first |
| , . | comma, decimal point |
| ... | and so on, upto |
| $a_1$, $a_2$ | a one, a two |
| a', a" | a single, or double stroke |
| = ≡ | equal |
| ≠ | not equal, unequal |
| ∼ | proportional |
| ≈ | approximate (round, c.a.) |
| ≙ | corresponds to (e.g. 1 cm ≙ 50 N) |
| < | less than |
| > | greater than |
| ≪ | much less than |
| ≫ | much greater than |
| ≦ ≧ | smaller or equal, max. equal<br>greater or equal, min. equal |

| Symbol | Enunciation |
|---|---|
| + | plus and |
| − | minus, lesser |
| · x | times |
| − / : | divided by |
| % | hundreth, of hundred, per cent |
| ‰ | thousandth, of thousand, per thousand |
| () [] {} | round, rectangular, curved brackets or parantheses |
| ∥ | parallel |
| ∦ | not parallel |
| ↑↑ | parallel in same direction |
| ↑↓ | parallel in opposite direction |
| ⊥ | perpendicular to, right angled to |
| △ | Triangle |
| ≅ | congruent |
| ∼ | similar to, proportional |

| Symbol | Enunciation |
|---|---|
| ∢ | Angle |
| $\overline{AB}$ | Segment A B |
| $\overset{\frown}{AB}$ | Arc A B |
| $\Delta$ | Delta (diff. Symbol) |
| $\Sigma$ | Sum |
| $\sqrt{}$ $\sqrt[n]{}$ | Squareroot of, nth root of |
| $\pi$ | Pi (3.14159) |
| ∞ | infinity |
| sin | sine |
| cos | cosine |
| tan | tangent |
| cot | cotangent |

## Indices

DIN 1304 (Nov. 71)

| Index | Significance | Index | Significance |
|---|---|---|---|
| a | outer | A | based on an area |
| i | inner | L | based on a length |
| max | maximal (greatest value) | v | based on a volume |
| min | minimal (smallest value) | eff | effective |
| negh | negligible | N | nominal value |
| e, el | electric | r | radial |
| n | standardized, standard state | r, rel | relative |
| 0 (zero) | value of a rest quiescent value, starting value | red | reduced |
| 1 $\alpha$ | start, inlet, primary | 2, $\beta$ | end, outlet, secondary |

# Mechanics

**Law of inertia**

Inertia or ability to preserve its state is the property of a body which keeps it in a state of rest or rectilinear motion without any external influence. It means that an external force is needed to be applied on the body to change its state of rest or straight line motion.

**Mass**

The property of inertia of a body opposing any change to its state of motion is the physical quantity of mass. The mass of a body is determined by comparing it to other bodies whose masses are known. Mass is expressed as the force of attraction to other bodies.

**Weight**

The magnitude of the mass of a body is determined by weighing. These magnitudes are given in mass units (basic-units kg) and are referred to not as weights but as mass. The balancing pieces (masses) are also known as weights. In business jargon weight is used as the short form for the weighing result of the quantity.

**Weight force**

The weight force is a product of the mass of body and the acceleration due to gravity. The acceleration with which a free body (without taking any additional force into consideration) falls, is $g = 9{,}81\ m/s^2$.
Units of weight force are the force units.

Weight force = mass · acceleration due to gravity

$$1\ N = 1\ kg\ m/s^2$$

**Basic law of Dynamics**

Any change in the state of motion of a body leads to an action of force on the body (see above, inertia and mass). The force gives the acceleration to the mass of a body

Force = mass · acceleration

$$F = m \cdot a$$

$F$ = force (N)
$m$ = mass (kg)
$a$ = speed $m/s^2$

**Representation of the forces**

A force is determined by its magnitude, direction and point of application. It is represented by a line segment with an arrow.

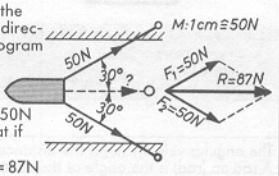
Point of application of force = starting point of the line segment

Magnitude of force = length of line segment (e.g. 1 cm ≙ 5 N): 4 cm ≙ 20 N

Direction of force = direction of arrow

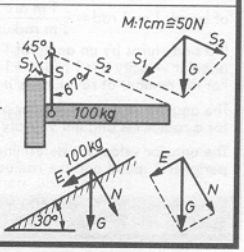
**Combination of forces**

When 2 forces $F_1$ and $F_2$ act on a body at an angle, the total effective force (resultant) in the magnitude and direction is determined by the diagonal (R) of the parallelogram whose sides are equivalent to the forces $F_1$ and $F_2$ respectively.
Ex.: On the bank of river, a boat is held with two ropes at an angle of 30° each and with the force of 50N on each rope. What force is required to hold the boat if only one rope is used in the middle?
From the law of parallelogram the required force R = 87N




**Resolution of a force**

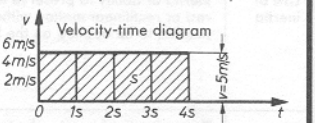
According to the parallelogram principle, one can resolve a force into two (or more) component force.
1. Example: A rope is to be replaced by two other ropes $S_1$ and $S_2$. What individual forces are to be applied on the ropes?
2. Example: With what force a body of 100 kg weight presses on its supporting base, which is inclined at angle $\alpha = 30°$? The pressure at the supporting base is always the pressure perpendicular to the supporting base. The required force $N$ is one part of the weight similarly also the force $E$. The parallel lines through the end point $G$ to $N$ and $E$ make the parallelogram $N = 87$ N.
(N can also be found trough trigonometrical computations)



## Uniform motion

A body moves equal distances *(s)* in equal intervals of time *(t)*. (The velocity remains constant).
Velocity *(v)* is the distance *(s)* per unit of time *(t)*.

| t = | 0 | 1s | 2s | 3s | 4s |
|---|---|---|---|---|---|
| s = | 0 | 5m | 10m | 15m | 20m |
| v = | | 5m/s | 5m/s | 5m/s | 5m/s |




### Linear and Curvilinear motion

Velocity = $\frac{\text{Distance covered}}{\text{time}}$ → $v = \frac{s}{t}$

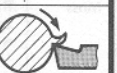
Distancce = Velocity · time → $s = v \cdot t$

Time = $\frac{\text{Distance covered}}{\text{velocity}}$ → $t = \frac{s}{v}$

Example: Planing
$s$ = length of workpiece $L = 1800 \text{ mm} = \frac{1800}{1000} \text{ m}$
$t$ = time per stroke $= 5.4 \text{ s} = \frac{5.4}{60} \text{ min}$

$$v = \frac{L}{t} = \frac{\frac{1800}{1000} \text{ m}}{\frac{5.4}{60} \text{ min}} = \frac{1800 \cdot 60}{1000 \cdot 5.4} = 20 \text{ m/min}$$

### Circular motion



Peripheral speed = Circumference of workpiece multiplied by revolutions per unit time (rpm) (or cutting speed) → $v = \pi \cdot d \cdot n$

Diameter = $\frac{\text{velocity}}{\pi \cdot \text{revolutions per unit time}}$ → $d = \frac{v}{\pi \cdot n}$

Number of revolutions per unit time = $\frac{\text{velocity}}{\text{circumference of workpiece}}$ → $n = \frac{v}{\pi \cdot d}$

Example: Turning

$d = 60 \text{ mm} = \frac{60}{1000} \text{ m}$
$n = 100 / \text{min}$

$$v = \pi \cdot d \cdot n = \frac{3.14 \cdot 60 \cdot 100}{1000} = 18.84 \approx 18 \text{ m/min}$$

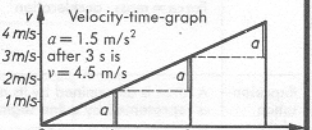
## Non-uniform motion (uniformly accelerated)

The velocity $v$ gradually increases per second $s$ at constant rate $a$. The acceleration $a$ (or deceleration) is the increase (or decrease) of the velocity per unit time.

Example: The velocity increases per second by 1.5 m/s and the acceleration

$$a = 1.5 \text{ m/s per second} = \frac{1.5 \text{ m/sec}}{\text{s}} = \frac{1.5 \text{ m}}{\text{s}^2} = 1.5 \text{ ms}^{-2}$$

| t = | 0 | 1s | 2s | 3s |
|---|---|---|---|---|
| s = | 0 | 0,75m | 3m | 6,75m |
| v = | 0 | 1,5m/s | 3m/s | 4,5m/s |




If the initial velocity $v = 0$ then

final velocity → $v = a \cdot t$ in m/s

Acc. → $a = \frac{v}{t}$ in m/s² dist. → $s = \frac{v}{2} \cdot t = \frac{b \cdot t}{2} \cdot t = \frac{b}{2} \cdot t^2$ in m

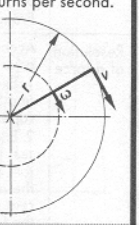
Example: $a = 1 \text{ cm/s}^2$; $t = 2 \text{ h}$; $v = ?$
$v = a \cdot t = 1 \text{ cm/s}^2 \cdot 2 \text{ h} = \frac{1 \text{ cm} \cdot 7200 \text{ s}}{\text{s}^2} = 7200 \text{ cm/s} = 72 \text{ m/s}$

$v = 6 \text{ m/s}$; $t = 3 \text{ s}$; $b = ?$
$a = \frac{v}{t} = \frac{6 \text{ m/s}}{3 \text{ s}} = 2 \text{ m/s}^2$ or $= 2 \text{ ms}^{-2}$

$v = 6 \text{ m/s}$; $t = 3 \text{ s}$; $s = ?$
$s = \frac{v}{2} \cdot t = \frac{3 \text{ m}}{\text{s}} \cdot 3 \text{ s} = 9 \text{ m}$

## Angular velocity

The angular velocity ($\omega$) is the distance which a point at 1 m distance from the centre turns per second.
A radian (rad) is the angle at the centre of a circle of radius 1 m subtended by an arc of length 1 m. $1 \text{ rad} = \frac{1 \text{ m arc}}{1 \text{ m radius}} = 1 \text{ m/m}$. A full angle is $360° = 12\,\pi \cdot \text{rad}$.




If a body turns by an angle of 1 rad, in 1 s, then the angular velocity is = 1 rad/s = 1 m/m s
For the number of revolutions $n$ per unit time. → $\omega = 2 \cdot \pi \cdot \text{rad} \cdot n \text{ (m/m s)}$

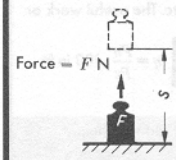
The angular velocity is the peripheral speed $v$ for a radius $r$ is angular velocity times radius → $v = \omega \cdot r \text{ (m/s)}$

The angular velocity is determined from the peripheral speed and the radius → $\omega = \frac{v}{r} \text{ (m/m s)}$

Example: $n = 10 \text{ 1/s}$; $d = 400 \text{ mm} = 0.4 \text{ m}$; $\omega = ?$; $v = ?$
Solution: $\omega = 2 \cdot \pi \cdot \text{rad} \cdot n = 6.28 \text{ m/m} \cdot 10 \text{ 1/s} = 62.8 \text{ 1/s}$ $v = \omega \cdot r = 62.8 \text{ 1/s} \cdot 0.2 \text{ m} = 12.56 \text{ m/s}$

## Work

Work $A$ = Force $F$ · distance $s$ ($s$ is measured in the direction of force)

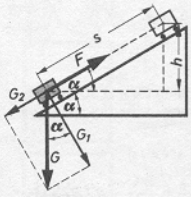



$$A = F \cdot s$$

$F$ in N; $s$ in m
$A$ becomes J
1 J = 1 Nm

$$A = G \cdot h$$

Example: If a weight of $F = 250$ N, is lifted through $s = 6$ m, or alternatively $F = 250$ N is moved in a particular direction, $s = 6$ m, then
$A = F \cdot s$
$A = 250\ \text{N} \cdot 6\ \text{m} = 1.5\ \text{kJ}$




The same amount of work is spent on lifting a load along an inclined plane as is spent in lifting the load vertically.

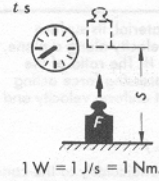
Example: What amount of work is required to move a car 1 km weighing 5000 kg along an inclined plane 1:100? $G = 50$ kN $h = 10$ m

Solution: $A = G \cdot h = 50\ \text{kN} \cdot 10\ \text{m} = 500\ \text{kJ}$
or $A = F \cdot s = 500\ \text{N} \cdot 1000\ \text{m} = 500\ \text{kJ}$

$F$ can be found by using the parallelogram of forces.
$G$ can be resolved into $G_1$ and $G_2$. $F = G_2$ and is put opposite to $G_2$. Calculation: $F = G_2 = G \cdot \sin \alpha$

## Power

Power $P$ = Work $A$ per unit of time




1 W = 1 J/s = 1 Nm/s

$$P = \frac{A}{t}$$

$A$ in J; $t$ in s;
$P$ becomes $W$

$$P = \frac{F \cdot s}{t}$$

$F$ in N; $s$ in m, $t$ in s
$P$ becomes $W$

$$P = F \cdot v$$

$F$ in N; $v$ in m/s
$P$ becomes $W$

Example: If a load of $F = 250$ N; $s = 6$ m is lifted in $t = 5$ s, the power is

$$P \frac{A}{t} = \frac{F \cdot s}{t} = F \cdot v$$

$$= \frac{250\ \text{N} \cdot 6\ \text{m}}{5\ \text{s}} = 300\ \text{W}$$

Power $P$ = Force $F$ · Speed $v$

Calculation:
75 kp m/s = 1 PS = 0.736 kW

$$P_{PS} = \frac{F \cdot v}{75}$$

102 kp m/s = 1 kW = 1.36 PS

$$P_{kW} = \frac{F \cdot v}{102}$$

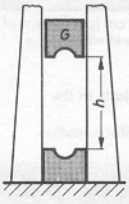
Example: What power in kW must a motor have to lift a weight of 1000 kg in 1 min by 12 m?

$$A = F \cdot s = 10\ \text{kN} \cdot 12\ \text{m} = 120\ \text{kJ}$$

$$P = \frac{A}{t} = \frac{120\ \text{kJ}}{60\ \text{s}} = 2\ \text{kW}$$

## Mechanical energy

Mechanical energy $E$ = Amount of work a body can do as a result of its position or it is velocity




$m$ = mass in kg

Stationary energy (potential still)

$$E_P = G \cdot h = m \cdot g \cdot h$$

$g$ = acceleration due to gravity
$h$ = height in m
$E_P$ = becomes then in Nm

1 N = 1 kg m/s²

Kinetic energy (moving, living)

$$E_K = \frac{m \cdot v^2}{2} \qquad v^2 = 2 \cdot g \cdot h$$

$E_K$ in Nm

Example: Assuming that a weighing $G = 2500$ N drops from a height $h = 2$ m: $E_P = G \cdot h = 2500\ \text{N} \cdot 2\ \text{m} = 5000\ \text{Nm}$.
Then the forge hammer drops. The kinetic energy attained by the hammer after a free fall of 2 m (i. e. at the time of striking the workpiece to the forged) must also be the same as its original potential energy.

E.g. $= \frac{m \cdot v^2}{2} = \frac{250\ \text{kg} \cdot 2 \cdot 9.81\ \text{m} \cdot 2\ \text{m}}{2\ \text{s}^2} = 5000\ \text{Nm}$

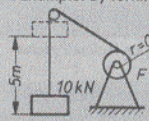
## Efficiency

In performing work a certain amount of losses occur due to friction or radiation etc. The useful work or power is always smaller than the works or power supplied.

Efficiency $\eta = \dfrac{\text{Useful work } An}{\text{total work done } Az}$ $\boxed{\eta = \dfrac{An}{Az}}$ or $\eta = \dfrac{\text{Useful power } Pn}{\text{Power supplied } Pz}$ $\boxed{\eta = \dfrac{Pn}{Pz}}$ $\eta = \dfrac{Pn}{Pz} \cdot 100$ in %

$\eta$ is always smaller than 1. The machine works better, if $\eta$ comes closer to 1.

1. Example: By turning the crankshaft of a winch 100 times, a weight $G = 10$ kN is lifted to a height of 5 m. What is the efficiency?

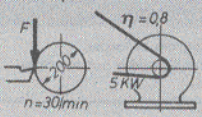



$An = G \cdot h = 10\text{ kN} \cdot 5\text{ m} = 50\text{ kJ}$

$Az = F \cdot s = F \cdot \pi \cdot d \cdot 100 = 200\text{ N} \cdot \pi \cdot 1\text{ m} \cdot 100 = 62.8\text{ kJ}$

$\eta = \dfrac{An}{Az} = \dfrac{50\text{ kJ}}{62.8\text{ kJ}} = 0.8 = 80\,\%$

2. Example: How much cutting force is required while turning a workpiece 200 mm Ø. $n = 30$ r.p.m.? The driving motor is rated at 5 kW and the efficiency of the driving wheel mechanism is 80 %



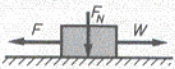

$\eta = \dfrac{Pn}{Pz}$ $Pn = \eta \cdot Pz = 0.8 \cdot 5\text{ kW} = 4\text{ kW}$ (1 kW = 1 kN m/s)

$Pn = F \cdot v$ $F = \dfrac{Pn}{v} = \dfrac{4\text{ kNm}}{s \cdot \pi \cdot d \cdot n} = \dfrac{4\text{ kNm}}{s \cdot 3.14 \cdot 0.2\text{ m} \cdot 30} = \dfrac{60\text{ s}}{0.314} = 1.275\text{ kN}$

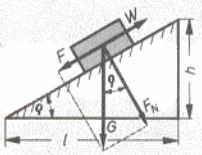
| | Steam turbine | Water turbines | Steam engines | Combustion engines | Electric motors |
|---|---|---|---|---|---|
| Efficiency | 0.18...0.22 | 0.85...0.9 | 0.15...0.2 | 0.25...0.30 | 0.8...0.9 |

## Friction

Sliding friction




The frictional resistance $W$ depends on the working material, its surface finish and the weight. If the body slides with uniform velocity along a plane, the driving force $F$ is equal to the frictional resistance $W$. The ratio of the frictional resistance $W$ to the normal force $F_N$ (= the pressing force acting perpendicularly to the supporting plane) is constant at uniform velocity and termed as the coefficient of friction ($\mu$).




$\boxed{\mu = \dfrac{W}{F_N}}$ $F = W = \mu \cdot F_N$ $\boxed{\mu = \tan \varrho = \dfrac{h}{l}}$

$W$ = Frictional resistance in $N = F$

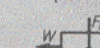
$F_N$ = Normal force (acting perpendicularly to the contact surface) in N (on horizontal surface $F_N = G$)

$\mu$ = Coefficient of friction (dimensionless)

$\varrho$ = Friction angle = The angle at which one must inclines a plane in order to overcome the frictional resistance.

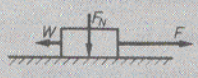
| Frictional coefficient for sliding motion | With static friction $\mu$ dry | With static friction $\mu$ lubricated | With kinetic friction $\mu$ dry | With kinetic friction $\mu$ lubricated |
|---|---|---|---|---|
| Steel on steel | 0.15 | 0.1 | 0.1 | 0.01 |
| Steel on grey Cast iron, bronze | 0.2 | 0.1 | 0.15 | 0.01 |
| Wood on wood | 0.65 | 0.2 | 0.3 | 0.1 |

1. Example: $F_N = G = 10$ kN; $\mu = 0.1$; How big should the force be without setting the body in motion?



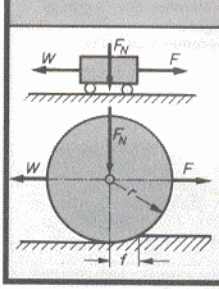

Solution: $F = W = \mu \cdot F_N = 0.1 \cdot 1\text{ kN} = 100\text{ N}$

2. Example: With what acceleration does a body move with $m = 10$ kg. Force $F = 50$ N and the coefficient of friction $\mu = 0.1$? (1 N = 1 kg m/s²)




Solution: Frictional resistance $W = \mu \cdot F_N = 0.1 \cdot 100\text{ N} = 10\text{ N}$

Accelerating force $F_l = F - W = 40\text{ N}$. $a = \dfrac{F_l}{m} = \dfrac{40\text{ kg m}}{10\text{ kg s}^2} = 4\text{ m/s}^2$




Rolling friction

$\boxed{W = \dfrac{f}{r} \cdot F_N}$

$f$ = Lever arm of the rolling friction in cm (coefficient of friction), (e. g. $f = 0.05$ cm for a steel wheel on a steel rail)

$r$ = Radius in cm

$F_N$ = normal force = acting perpendicularly to the contact surface (weight force)

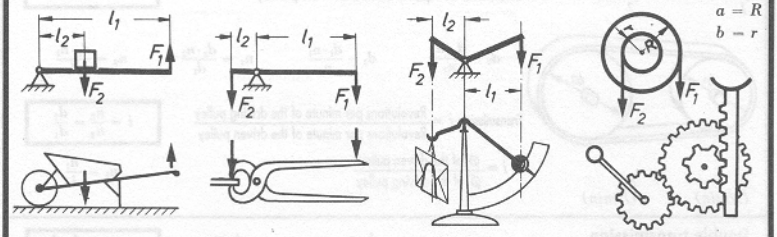
$W$ = Resistance to rolling in $N$. With uniform motion $W = F$ = traction force.

Example: What amount of force is necessary to maintain a uniform rolling motion of rail axle with wheels weighing 10 kN, wheel diameter 1 m and $f = 0.05$ cm?

Solution: $F = W = \dfrac{f}{r} \cdot F_N = \dfrac{0.05\text{ cm} \cdot 10\text{ kN}}{50\text{ cm}} = 10\text{ N}$

## The lever

First class lever | Second class lever | Bellerank lever | Wheel and axle winch




$$F_1 \cdot l_1 = F_2 \cdot l_2 \quad \text{(Nm = Nm)}$$

Force $F_1$ · lever arm $l_1$ = Force $F_2$ · lever arm $l_2$

Moment of force $M_1$ = Moment of force $M_2$

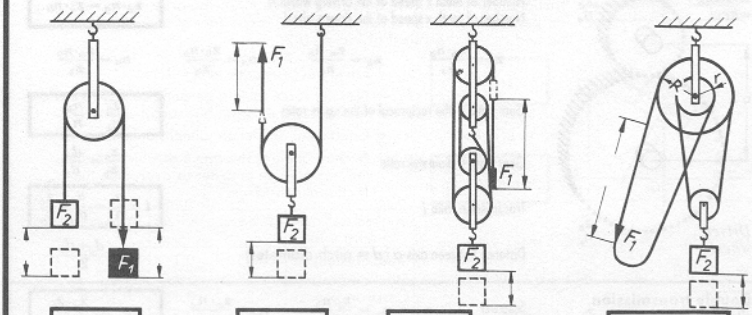
clockwise moment = anti-clockwise moment

The lever arms is always measured starting from the fulcrum and perpendicular to the line of action of force

## The pulley

With a machine, the work is not saved, but is distributed in another way with respect to the force and path of action. Work $W_1$ = work $W_2$ (without friction)

Fixed pulley | Moveable pulley | Vertical set of pulleys | Differential pulley



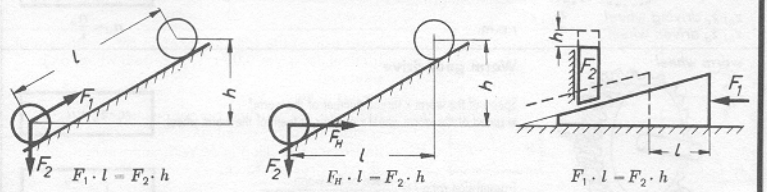

$F_1 = F_2$

$F_1 = \frac{1}{2} F_2$

$F_1 = \frac{F_2}{n}$ $n$ = number of pulleys

$F_1 = F_2 \cdot \frac{R - r}{2R}$

## The inclined plane, the wedge




$F_1 \cdot l = F_2 \cdot h$

$F_1 = \frac{F_2 \cdot h}{l}$

$F_H \cdot l = F_2 \cdot h$

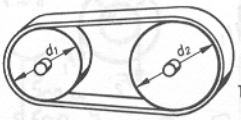
$F_H = \frac{F_2 \cdot h}{l}$

$F_1 \cdot l = F_2 \cdot h$

$F_1 = \frac{F_2 \cdot h}{l}$

## Simple transmission

*driving pulley 1* — *driven pulley 2*




$n_1$ (1/min) $n_2$ (1/min)

### Belt drive

Diameter x r.p.m. of the driving pulley = Diameter x r.p.m. of the driven pulley

$$d_1 \cdot n_1 = d_2 \cdot n_2$$

$$d_1 = \frac{d_2 \cdot n_2}{n_1} \qquad d_2 = \frac{d_1 \cdot n_1}{n_2} \qquad n_1 = \frac{d_2 \cdot n_2}{d_1} \qquad n_2 = \frac{d_1 \cdot n_1}{d_2}$$

Transmission $i = \frac{\text{Revolutions per minute of the driving pulley}}{\text{Revolutions per minute of the driven pulley}}$

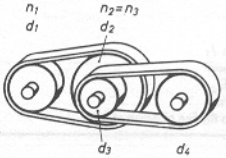
or $i = \frac{\text{Ø of the driven pulley}}{\text{Ø of the driving pulley}}$

$$i = \frac{n_1}{n_2} = \frac{d_2}{d_1}$$

$$n_2 = \frac{n_1}{i}$$

## Double transmission

(Series drive)




Revolutions/min: $n_2 = \frac{d_1 \cdot n_1}{d_2}$ $\qquad n_4 = \frac{d_3 \cdot n_3}{d_4}$

$$n_4 = n_1 \cdot \frac{d_1 \cdot d_3}{d_2 \cdot d_4}$$

Total transmission = product of industrial transmission ratios

$$i = i_1 \cdot i_2$$

$$i_1 = \frac{n_1}{n_2} \qquad i_2 = \frac{n_3}{n_4}$$

Total transmission ratio

$$i = \frac{n_1}{n_4} = \frac{d_2 \cdot d_4}{d_1 \cdot d_3}$$

Revolutions per minute:

$$n_4 = \frac{n_1}{i}$$

## Simple transmission

### Gear drive

*Driving wheel* $z_a$ $n_a$

*Driven wheel* $z_b$ $n_b$

a

Number of teeth x speed of the driving wheel = Number of teeth x speed of the driven wheel

$$z_a \cdot n_a = z_b \cdot n_b$$

$$z_a = \frac{z_b \cdot n_b}{n_a} \qquad z_b = \frac{z_a \cdot n_a}{n_b} \qquad n_a = \frac{z_b \cdot n_b}{z_a} \qquad n_a = \frac{z_a \cdot n_a}{z_b}$$

Gear ratio = the reciprocal of the r.p.m. ratio

$$\frac{z_a}{z_b} = \frac{n_b}{n_a}$$

Gear ratio = diameter ratio

$$\frac{z_a}{z_b} = \frac{d_a}{d_b}$$

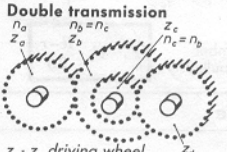
Transmission ratio $i$

$$i = \frac{n_a}{n_b} = \frac{d_b}{d_a} = \frac{z_b}{z_a}$$

Distance between axis $a$ ($d$ = pitch diameter)

$$a = \frac{d_a + d_b}{2}$$

## Double transmission




Speed $n_b = n_c = \frac{z_a \cdot n_a}{z_b}$ $\qquad n_d = \frac{z_c \cdot n_c}{z_d}$

$$n_d = n_a \cdot \frac{z_a \cdot z_c}{z_b \cdot z_d}$$

Total transmission = product of industrial transmission ratios:

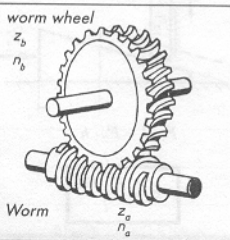
$$i = i_1 \cdot i_2$$

Total transmission ratio:

$$i = \frac{n_a}{n_d} = \frac{z_b \cdot z_d}{z_a \cdot z_c}$$

r.p.m.

$$n_d = \frac{n_a}{i}$$




### Worm gear drive

Speed of the worm x thread number of the worm* = speed of the worm wheel x number of teeth of the worm wheel

$$n_a \cdot z_a = n_b \cdot z_b$$

Transmission ratio $i = \frac{\text{speed of the worm}}{\text{speed of the worm wheel}}$

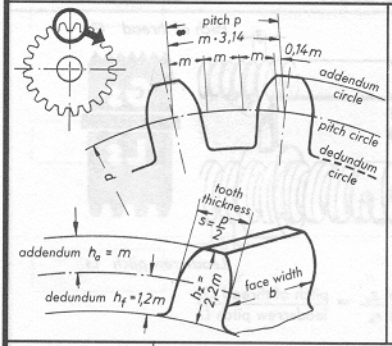
$$i = \frac{n_a}{n_b}$$

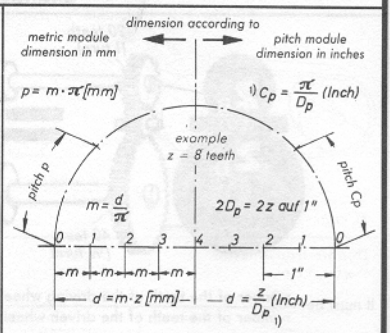
or $i = \frac{\text{Number of teeth of the worm wheel}}{\text{thread number of the worm}}$

$$i = \frac{z_b}{z_a}$$

* With single start thread worms $z_a = 1$, and for double start thread worms $z_a = 2$.

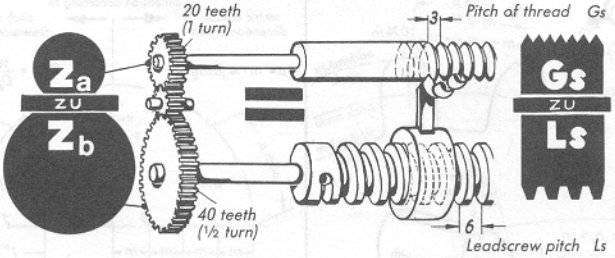
# Dimensions of gears




| | | |

## Change gears



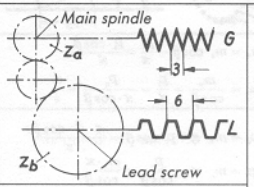

It must be: $\frac{\text{number of the teeth of the driving wheel } z_a}{\text{number of the teeth of the driven wheel } z_b} = \frac{\text{pitch of thread } Gs}{\text{leadscrew pitch } Ls}$

$$\boxed{\frac{z_a}{z_b} = \frac{Gs}{Ls}}$$

Pitch ratio $G_s / L_i$ must be so transformed that it may correspond to the number of teeth of change gear set. There are a large variety of change-gear sets. A typical set contains the following gears:
20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 110 120 125 127

## Lead screw with mm pitch

### Screw thread with mm pitch

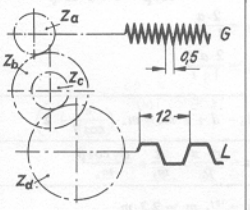



Simple transmission

Main screw: 3 mm pitch
Lead screw: 6 mm pitch

$$\frac{z_a}{z_b} = \frac{Gs}{Ls} = \frac{3}{6} = \frac{1}{2} = \frac{20}{40}$$

$z_a = 20$ teeth
$z_b = 40$ teeth
or 25 teeth, 50 teeth




Double gear transmission

Screw: 0.5 mm pitch
Lead screw: 12 mm pitch

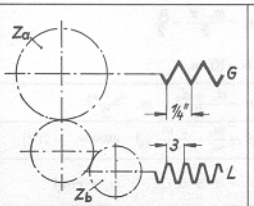
$$\frac{Gs}{Ls} = \frac{0{,}5}{12} = \frac{1}{24}$$

No convenient numbers of teeth can be found. The ratio would have to be split into 2 sub-ratios.

$$\frac{z_a \cdot z_c}{z_b \cdot z_d} = \frac{1}{24} = \frac{1}{4} \cdot \frac{1}{6} = \frac{25}{100} \cdot \frac{20}{120}$$

Driving gears: $z_a$ and $z_g$ = 25 and 20 teeth
Driven gears: $z_e$ and $z_g$ = 100 and 120 teeth

### Screw threads with pitch in inches



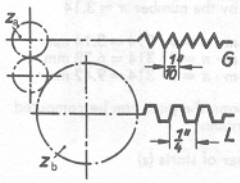

Screws: 4 threads in $1'' = \frac{1''}{4}$ pitch $= \frac{25.4}{4}$ mm pitch
Lead screw: 3 mm pitch

$$\frac{z_a}{z_b} = \frac{Gs}{L_i} = \frac{\frac{1''}{4}}{3} = \frac{25{,}4}{4} \cdot \frac{1}{3} = \frac{12{,}7 \cdot 1}{2 \cdot 3} = \frac{127}{60}$$

$z_a = 127$ teeth
$z_b = 60$ teeth

# Lead screw with pitch in inches

## Screw threads with pitch in inches

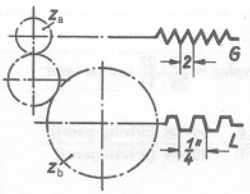



Main screw: 10 threads per inch = 1/10" pitch
Lead screw: 4 threads per inch = 1/4" pitch

$$\frac{z_a}{z_b} = \frac{Gs}{Ls} = \frac{\frac{1}{10}}{\frac{1}{4}} = \frac{1}{10} \cdot \frac{4}{1} = \frac{4}{10} = \frac{40}{100}$$

$z_a = 40$ teeth
$z_b = 100$ teeth

## Screw threads with pitch in millimeter

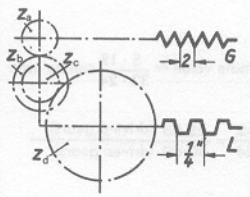



Main Screw: 2 mm pitch
Lead screw: 4 threads to an inch = $\frac{1''}{4}$ pitch = $\frac{25{,}4}{4}$ mm pitch

$$\frac{z_a}{z_b} = \frac{Gs}{Ls} = \frac{2}{\frac{25{,}4}{4}} = \frac{2 \cdot 4}{25{,}4} = \frac{4}{12{,}7} = \frac{40}{127}$$

$z_a = 40$ teeth
$z_b = 127$ teeth

If the threads should be cut without using 127 teeth wheel, then an approximate value $\frac{1600}{63}$ or $\frac{432}{17}$ is used for the value 25.4
The resulting error in pitch amounts to 0.16 mm and 0.43 mm on 1000 mm thread length.




25.4 is replaced by $\frac{1600}{63}$

$$\frac{z_a}{z_b} = \frac{Gs}{Ls} = \frac{2}{\frac{25{,}4}{4}} = \frac{8}{25{,}4} = \frac{8}{\frac{1600}{63}} = \frac{8 \cdot 63}{1600}$$

$$= \frac{63}{200} = \frac{7 \cdot 9}{10 \cdot 20} = \frac{35}{50} \cdot \frac{45}{100}$$

Driving wheels: $z_a$ and $z_c = 35$ and 45 teeth
Driven wheels: $z_b$ and $z_d = 50$ and 100 teeth

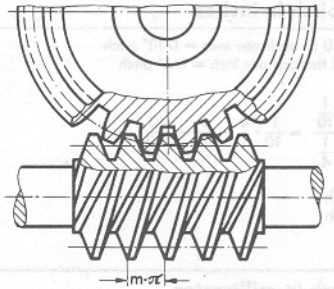
25.4 is replaced by $\frac{432}{17}$

$$\frac{z_a}{z_b} = \frac{Gs}{Ls} = \frac{2}{\frac{25{,}4}{4}} = \frac{8}{25{,}4} = \frac{8}{\frac{432}{17}} = \frac{8 \cdot 17}{432}$$

$$= \frac{17}{54} = \frac{17 \cdot 1}{9 \cdot 6} = \frac{85 \cdot 20}{45 \cdot 120}$$

Driving wheels: $z_a$ and $z_c = 85$ and 20 teeth
Driven wheels: $z_b$ and $z_d = 45$ and 120 teeth

# Screw threads with module pitch




Screw threads with module pitch are normally used for worms in worm gear drives. The pitch can always be divided by the number $\pi = 3.14$

Module 1 = m · π = 1 · 314 = 3.14 mm
Module 2 = m · π = 2 · 314 = 6.28 mm
Module 3 = m · π = 3 · 314 = 9.42 mm

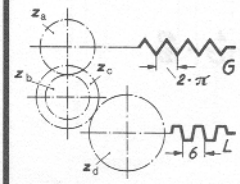
With multi-start worms, the pitch can be computed by applying the formula:

m · π · number of starts (z)

Module m has the pitch m · π

Lead screw with mm-pitch

Screw (worm): Single start module 2 mm; pitch 2 π mm
Lead screw: pitch 6 mm




$$\frac{z_a}{z_b} = \frac{Gs}{Ls} = \frac{2 \cdot \pi}{6};$$

for π, the approximate value $\approx \frac{32 \cdot 27}{25 \cdot 11}$ can be used

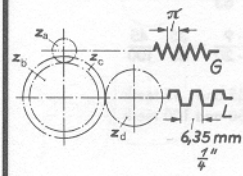
$$\frac{z_a}{z_b} = \frac{Gs}{Ls} = \frac{2 \cdot \pi}{6} = \frac{2 \cdot 32 \cdot 27}{6 \cdot 25 \cdot 11} = \frac{32 \cdot 9}{25 \cdot 11} = \frac{\mathbf{32 \cdot 36}}{\mathbf{25 \cdot 44}} \begin{matrix}\text{(driving gears)} \\ \text{(driven gears)}\end{matrix}$$

Approximate values for π

| $\pi \approx$ | $\frac{8 \cdot 97}{13 \cdot 19}$ | $\frac{25 \cdot 47}{22 \cdot 17}$ | $\frac{19 \cdot 21}{127}$ | $\frac{32 \cdot 27}{25 \cdot 11}$ | $\frac{22}{7}$ |
|---|---|---|---|---|---|
| Error in mm/m | 0,034 | 0,038 | 0,044 | 0,072 | 0,402 |

Lead screw with pitch in inches

Screw (worm): Single start 1 mm; pitch 1 · π mm
Lead screw: 4 threads per inch; pitch $\frac{1''}{4} = \frac{25.4}{4}$ mm




$$\frac{z_a}{z_b} = \frac{Gs}{Ls} = \frac{1 \cdot \pi}{\frac{25,4}{4}} = \frac{1 \cdot \pi \cdot 4}{25,4};$$

for $\frac{\pi}{25,4} = \frac{\pi}{1''}$ the approximate value $\approx \frac{5 \cdot 19}{32 \cdot 24}$ can be used

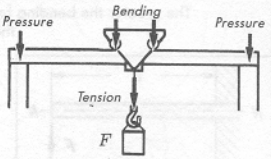
$$\frac{z_a}{z_b} = \frac{Gs}{Ls} = \frac{\pi \cdot 4}{25,4} = \frac{5 \cdot 19 \cdot 4}{32 \cdot 24} = \frac{5 \cdot 19}{8 \cdot 24} = \frac{\mathbf{25 \cdot 95}}{\mathbf{80 \cdot 60}} \begin{matrix}\text{(driving gears)} \\ \text{(driven gears)}\end{matrix}$$

Approximate values for $\frac{\pi}{1''}$

| $\frac{\pi}{1''} \approx$ | $\frac{47}{4 \cdot 95}$ | $\frac{5 \cdot 19}{32 \cdot 24}$ | $\frac{12}{97}$ | $\frac{22 \cdot 5}{7 \cdot 127}$ | $\frac{5 \cdot 9}{26 \cdot 14}$ |
|---|---|---|---|---|---|
| Errors in mm/m | 0,005 | 0,106 | 0,214 | 0,402 | 0,472 |

# Tensile and compressive strength

Strength = the internal resistance (cohesive force) of the molecules against a load (tension, compression, shear, torsion)



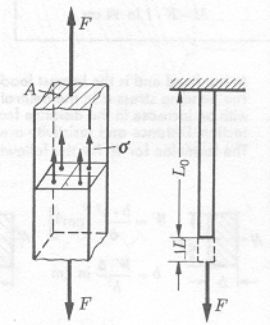

If a force $F$ (N) acts on a rod, then a stress (N/mm²) is created within the material, which opposes the externally applied force $F$

Tensile or compressive stresses $\sigma$ (sigma) = tensile or compressive load per unit area (cm², mm²)

| | | |
|---|---|---|
| $\sigma = \frac{F}{A}$ [N/mm²] | $F = A \cdot \sigma$ [N] | $A = \frac{F}{\sigma}$ [cm²] |

The stress at the breaking point is the tensile strength $\sigma_n$ of the material. Structural parts are loaded with a permissible stress $\sigma_{negh}$ which amounts only to

$\frac{1}{15} \cdots \frac{1}{5}$ of the tensile strength




Strain $\varepsilon$ = change in length per unit length (cm; mm)

$$\varepsilon = \frac{\Delta L}{L_o} = \frac{\text{Elongation}}{\text{original length}}$$

The strain upto the breaking point is designated as breaking strain and is given in percentage (%).

$$\text{Therefore } \varepsilon = \frac{\Delta L \cdot 100\%}{L_o}$$

$\sigma$ = tension or compression
$\sigma_s$ = yield point
$\sigma_{0.2}$ = limit
$\sigma_{per}$ = safety limit
$\upsilon_{Ny}$ = safety
$F$ = Force applied (N)
$A$ = Cross section (mm² o. cm²)

Example: ⌀ 8 St. 34-2 Tensile strength $\sigma$ = ?

$F = 2000$ N $\quad \sigma = \frac{F}{A} = \frac{2000 \text{ N}}{50 \text{ mm}^2} = 40$ N/mm²

Factor of safetey $\nu = \frac{\sigma_s}{\sigma_s} = \frac{205}{40}$

it is merely 5 times safety

# Shear strength

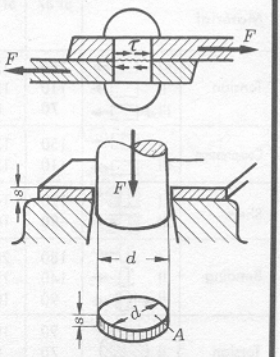
If a force $F$ tries to move two adjacent surfaces in two opposite directions, (rivet, cutting, tools etc.) then the resistance of the material is referred to as the shear strength of a material

Shear stress $\tau$ = shear stress per unit area (mm² · cm²) of the shearing surfaces

| | | |
|---|---|---|
| $\tau = \frac{F}{A}$ [N/mm²] | $F = A \cdot \tau$ [N] | $A = \frac{F}{\tau}$ [mm²] |

The given shearing for materials $\tau_n$ is the breaking strength, at which a material is said to be cut or sheared

The shear strength is approximately $\frac{4}{5}$ of the tensile strength

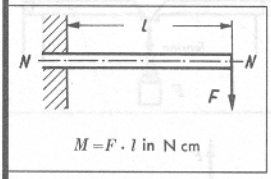



Example: A sheet of metal 2 mm thick and a shear strength of 400 N/mm² has to be punched with $d$ = 35 mm. How much force $F$ is required?

$F = A \cdot \tau = \pi \cdot d \cdot s \cdot \tau = 110 \text{ mm} \cdot 2 \text{ mm} \cdot 400 \text{ N/mm}^2 = 88 \text{ kN}$

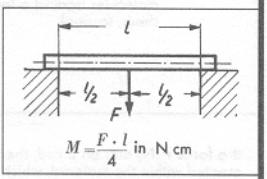
# Bending strength

The greater the bending force $F$ (N) and the longer the arm of the lever $l$ (cm) are, the larger is the bending moment



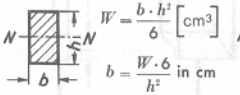

$M = F \cdot l$ in N cm

The product of the force and lever arm is termed as the bending moment $M$



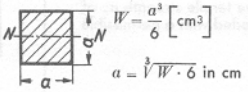

$M = \frac{F \cdot l}{4}$ in N cm

At the fixed end is the largest loading and also the largest bending moment.
The bending stress $\sigma$ in the neutral layer (neutral axis N-N) is equal to zero. The stresses increase with an increase in the distance from neutral axis and decrease with the resistivity of the cross section. Distance and resistivity are expressed by the moment of resistance $W$.
The formulae for $W$ for the following cross sections:



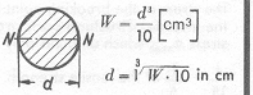

$W = \frac{b \cdot h^2}{6}$ [cm³]

$b = \frac{W \cdot 6}{h^2}$ in cm




$W = \frac{a^3}{6}$ [cm³]

$a = \sqrt[3]{W \cdot 6}$ in cm




$W = \frac{d^3}{10}$ [cm³]

$d = \sqrt[3]{W \cdot 10}$ in cm

The bending moment can increase with an increase in the permissible stress and moment of resistance. It is:

$M = \sigma_{per} \cdot W$ N cm

One generally knows the bending moment (from $F \cdot l$) and the permissible stress of a particular material.
The moment of resistance can be derived and hence the cross-sectional dimensions from it: $W = \frac{M}{\sigma_{per}}$ [cm³]

The bending moment is maximum at the point of maximum stress

Example:
Find the diameter of a horizontal bar of 160 cm length. A load placed at the centre of the bar weight 1 kN · $\sigma_{per} = 7$ kN/cm²

$W = \frac{M}{\sigma_{per}} \cdot \frac{F \cdot l}{4 \cdot \sigma_{per}} = \frac{1 \text{ kN} \cdot 160 \text{ cm} \cdot \text{cm}^2}{4 \cdot 7 \text{ kN}} = 5.7 \text{ cm}^3$ $d = \sqrt[3]{W \cdot 10}$ $\sqrt[3]{57}$ 3.87 cm

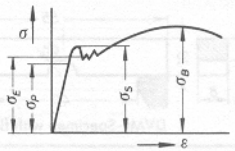
**Permissable stresses $\sigma$ (N/mm²) in mechanical engineering**

| Material | | St 37 | St 42 | St 50 | St 60 | C 35 | C 45 | C 60 | GG-20 | GG-25 | GS-45 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | tempered | | | | | |
| Tension | *I | 150 | 170 | 200 | 240 | 250 | 300 | 360 | 60 | 90 | 150 |
| | II | 110 | 120 | 150 | 170 | 180 | 210 | 250 | 50 | 70 | 110 |
| | III | 70 | 80 | 100 | 110 | 110 | 130 | 150 | 40 | 50 | 80 |
| Compression | I | 150 | 170 | 200 | 240 | 250 | 300 | 360 | 170 | 220 | 150 |
| | III | 110 | 120 | 150 | 170 | 180 | 210 | 250 | 90 | 120 | 110 |
| Shear | I | 120 | 140 | 160 | 190 | 200 | 240 | 290 | 80 | 120 | 120 |
| | III | 90 | 100 | 120 | 140 | 150 | 170 | 210 | 60 | 80 | 90 |
| Bending | I | 180 | 200 | 240 | 290 | 300 | 360 | 430 | 100 | 150 | 180 |
| | II | 140 | 150 | 180 | 220 | 220 | 250 | 310 | 80 | 110 | 140 |
| | III | 90 | 100 | 120 | 140 | 140 | 150 | 190 | 50 | 70 | 100 |
| Torsion | I | 90 | 100 | 120 | 140 | 150 | 180 | 220 | 60 | 90 | 90 |
| | II | 70 | 80 | 100 | 110 | 120 | 140 | 160 | 50 | 70 | 70 |
| | III | 50 | 60 | 75 | 90 | 80 | 90 | 110 | 30 | 50 | 50 |

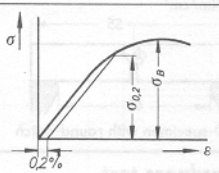
*I: dead load II: varying load between zero and a maximum value
III: Varying in the direction of force (safety against $\sigma_z : v = 1,5, \ldots 4$)

## Concepts for strength testing

DIN 1602 (Feb. 44)




Tensile test




Stress: $\sigma = \frac{P}{F_o}$

Load: $P$

Original cross-section of the specimen: $F_o$

Strain: $\varepsilon = \frac{L}{L_o}$

Original length of the test piece: $L_o$

Change in length: $\Delta L$

Tensile stress: $\sigma_z$

Compressive stress: $\sigma_d$

Shear stress: $\tau_s$

Torsional stress: $\tau_t$

Static strength: $\sigma_B$; $\tau_B$

1) Yield point: $\sigma_s$
0.2-limit: $\sigma_{02}$
2) Elastic limit: $\sigma_E$
3) Proportional limit: $\sigma_p$

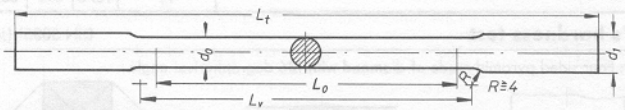
1) In case the yield point is not sharply marked, the yield stress is measured at 0.2 % of the permanent strain.

2) Hook's law is applicable upto elastic limit $\sigma = \varepsilon \cdot E$ ($E$-elasticity modulus)

3) The material is absolutely elastic till the proportionality limit. The stress is proportional to the strain.

## Tensile test specimen for steel

DIN 50125 (Apr. 51)




**Test specimen A:** (Notation e.g. Tension test specimen A 10 · 50 DIN 50125)

| $d_0$ | $d_1$ | Short proportional bar $L_o$ | $L_v$ | $L_t$ | $L_o = 5 \cdot d_o$ | Longer proportional bar $L_o$ | $L_v$ | $L_t$ | $L_o = 10 \cdot d_o$ |
|---|---|---|---|---|---|---|---|---|---|
| 6 | 8 | 30 | 36 | 95 | | 60 | 66 | 125 | |
| 8 | 10 | 40 | 48 | 115 | | 80 | 88 | 155 | |
| 10 | 12 | 50 | 60 | 140 | | 100 | 110 | 190 | |
| 12 | 15 | 60 | 72 | 160 | | 120 | 132 | 220 | |

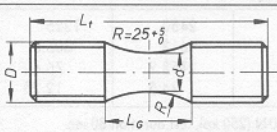
**Flat test specimen E:** (Notation e.g. Test specimen E 5 · 10 · 40 DIN 50125)

| $a$ | $b$ | $B$ | $L_o$ | $L_v$ | $L_t$ |
|---|---|---|---|---|---|
| 5 | 10 | 15 | 40 | 50 | 140 |
| 5 | 16 | 22 | 50 | 65 | 155 |
| 6 | 20 | 27 | 60 | 80 | 210 |
| 8 | 25 | 33 | 80 | 105 | 260 |
| 10 | 25 | 33 | 90 | 115 | 275 |

Short proportional bar
$B$: Width of head (1.2 $b$ + 3 mm)
$F_o$: Cross section of test specimen
$L_v$: Test length of specimen = $L_o + b$
$L_o$: Gauge length (= 5.65 $\sqrt{F_o}$)

## Tensile test specimen for grey casting

DIN 50109 (March 68)



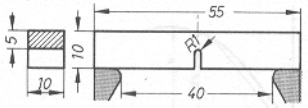

| $d$ | $D$ | $L_G$ | $L_t$ |
|---|---|---|---|
| 6 | M 10 | 20 | 46 |
| 8 | M 12 | 21 | 53 |
| 10 | M 16 | 23 | 63 |
| 12.5 | M 20 | 25 | 73 |
| 16 | M 24 | 27 | 87 |
| 20 | M 30 | 30 | 102 |

Notations:
Tensile test specimen 10 g DIN 50109 (for separat. casted)
Tensile test specimen 10 a DIN 50109 (for cast. test specim.)
Tensile test specimen 10 s DIN 50109 (for evolved specim.)

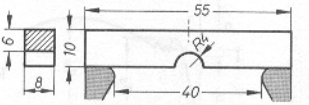
## Impact bending test (notched-bar test)

DIN 50115 (Nov. 66)

Impact strength $a_k$ = the work resulting from an impact during the test, is divided by cross-section of the specimen in Nm/cm²




ISO-specimen with round-notch

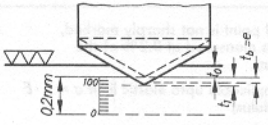



DVMF-Specimen with flat notch

## Rockwell-hardness test

DIN 50103 (Dec. 72)

Methods with cones (120°, $R = 0.2$ mm)
20...70 HRC for hardened steel
60...88 HRA for very hard substances



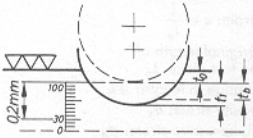

unit of hardness

$$e = \frac{t_b}{0.002\ \text{mm}}$$

Hardness: 100 – $e$ HRC

$t_o$ = penetration depth under the pre-test force $F_o$
$t_1$ = penetration depth under the test force $F_1$
$F$ = total test force $F_0 + F_1$
$t_b$ = permanent penetration depth in after applying force $F_1$ on $F_o$

Methods with balls (/ 1.5875 mm)
35...100 HRB for medium hardness
60...100 HRF for thin sheets, brass



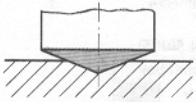

Hardness: 130 – $e$ HRB

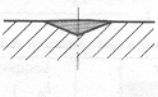
| test forces in N | | | | |
|---|---|---|---|---|
| Methods | C | A | B | F |
| $F_o$ | 98 | 98 | 98 | 98 |
| $F_1$ | 1373 | 490 | 883 | 490 |

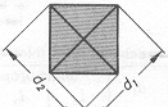
## Vicker's hardness test

DIN 50351 (Jan. 73)

Test body: Four sided pyramid made of diamond with 136 deg. spherical angle








$$d = \frac{d_1 + d_2}{2}$$

| Preferred test forces F: | | | | | | |
|---|---|---|---|---|---|---|
| N | 49 | 98 | 196 | 294 | 490 | 980 |
| kp | 5 | 10 | 20 | 30 | 50 | 100 |

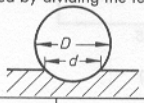
$$HV = 0.189\ \frac{F}{d^2}\quad (F \text{ in N})$$

HV = 0.189 times test force divided by $d^2$

## Brinell hardness test

DIN 50351 (Jan. 73)

The test body are steel or hard metal balls with 10, 5, 2.5 or 1 mm diameter. The Brinell hardness HB is obtained by dividing the test force by the indented surface area of the ball




$$HB = \frac{0{,}102 \cdot F}{A} = \frac{0{,}102 \cdot 2 \cdot F}{\pi \cdot (D - \sqrt{D^2 - d^2})}\quad (F \text{ in N})$$

$$\text{degree of load} = \frac{0{,}102 \cdot F}{D^2}$$ (should be chosen in such a way that $d$ lies between 0.2 and 0.7 $D$)

| | Degree of load ($F$ in $N$) | | | | |
|---|---|---|---|---|---|
| | 30 | 10 | 5 | 2.5 | 1.25 |
| Hardn. range | 67...450 HB | 22...315 HB | 11...158 HB | 6...78 HB | 3...39 HB |
| Material | Steel. cast iron | Light metal copper, brass | Alum., Magnesium, Zinc | Bearing metal | Lead tin |
| Ball-/ | Test force $F$ in $N$ | | | | |
| D = 10 | 29420 | 9800 | 4900 | 2450 | 1225 |
| D = 5 | 7355 | 2450 | 1225 | 613 | 306.5 |
| D = 2.5 | 1840 | 613 | 306.5 | 153.2 | 76.6 |
| D = 1 | 294 | 98 | 49 | 24.5 | 12.25 |

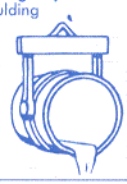
Example: 120 HB 5/250/30 (Hardness 120 HB, ball 5 mm / Test force 2450 N (250 kp), test duration 30 sec.

# Classification of the manufacturing processes

DIN 8580 (Oct. 63)

Cohesiveness created

**Main group 1**
Moulding
(1)



1.1 From a gaseous state, e.g., transformation of a metallic vapour to a solid state

1.2 From a liquid state e.g. casting of metals or synthetic materials

1.3 By the electrolysis e.g. galvanic shaping of the solid body

1.4 From a granular state e.g. compressing metal power followed with sintering

Cohesiveness kept

**Main group 2**
Forming
(2)

2.1 Pressure forming (DIN 8583) e.g. rolling, forging

2.2 Forming under combination of tensile & compressive conditions (DIN 8584) e.g. wire drawing, deep drawing

2.3 Forming under tensile conditions (DIN 8585) e.g. elongation

2.4 Forming by bending (DIN 8586) e.g. folding, flexion

2.5 Forming under shearing conditions (DIN 8587) e.g. torsion, pounding

**Main group 6**
Changing of properties of material

6.1 Rearranging of the material particles e.g. hardening, tempering, magnetising

Cohesiveness reduced

Forming

**Main group 3**
Separating

3.1 Splitting (DIN 8588) e.g. cutting, breaking

3.2 Chiping e.g. drilling, turning, grinding

3.3 Wear e.g. chemically, physically

3.4 Dividing e.g. dismantling, pressing out

3.5 Purifying e.g. combustion, degreasing

6.2 Separating e.g. decarbonising, tempering

Cohesiveness increased

**Main group 4**
Joining
(DIN 8593)

4.1 By putting together e.g. inserting, suspending

4.2 By filling in e.g. pouring in, impregnating

4.3 By pressing in e.g. screwing, shrinking

4.4 By moulding e.g. remoulding of solids

4.5 By transforming e.g. rabeting, riveting

4.6. By material joining e.g. welding, soldering, sticking

6.3 Introducing material. Particles e.g. carbiding, nitriding

**Main group 5**
Coating
(3)

5.1 From a gaseous state e.g. vapourization of metals

5.2 From a liquid state e.g. varnishing, weld coating

5.3 From the ionized state e.g. galvanizing

5.4 From a granular state, e.g. powder spraying

(1) Methods of moulding are used in the main groups joining and coating.
(2) Methods of forming are also used for joining
(3) Methods wherein foils, sheets or veneer sheets are involved are not counted in any of the above groups.

# FORM

## Standard sizes

| Standards | | | DIN 323 x Feb. 57 |
|---|---|---|---|
| Basic series | | | |
| R 5 | R 10 | R 20 | R 40 |
| **1.00** | 1.00 | 1.00 | 1.00 |
| | | | 1.06 |
| | | | 1.12 |
| | | | 1.18 |
| | 1.25 | 1.25 | 1.25 |
| | | | 1.32 |
| | | | 1.40 |
| | | | 1.50 |
| **1.60** | 1.60 | 1.60 | 1.60 |
| | | | 1.70 |
| | | | 1.80 |
| | | | 1.90 |
| | 2.00 | 2.00 | 2.00 |
| | | | 2.12 |
| | | | 2.24 |
| | | | 2.36 |
| **2.50** | 2.50 | 2.50 | 2.50 |
| | | | 2.65 |
| | | | 2.80 |
| | | | 3.00 |
| | 3.15 | 3.15 | 3.15 |
| | | | 3.35 |
| | | | 3.55 |
| | | | 3.75 |
| **4.00** | 4.00 | 4.00 | 4.00 |
| | | | 4.25 |
| | | | 4.50 |
| | | | 4.75 |
| | 5.00 | 5.00 | 5.00 |
| | | | 5.30 |
| | | | 5.60 |
| | | | 6.00 |
| **6.30** | 6.30 | 6.30 | 6.30 |
| | | | 6.70 |
| | | | 7.10 |
| | | | 7.50 |
| | 8.00 | 8.00 | 8.00 |
| | | | 8.50 |
| | | | 9.00 |
| | | | 9.50 |

Application of standards:
Technical parameters which can be expressed in numbers:
Dimensions *(d · h · l)*
Strength: *(A, F)*
In power machines *(p, n)*
Series R 5 is preferred to R 10 and these in turn are preferred to R 20
Numbers above 10 or below 1 may be achieved by multiplication or division by 10, 100 etc

| Standard sizes (mm) | | | | | | | | DIN 3 Feb. 55 |
|---|---|---|---|---|---|---|---|---|
| | | | | 100 | | | | 370 |
| | | | | 105 | | | | 375 |
| | 1 | 10 | | 110 | | | | 380 |
| | | | 1.1 | 115 | | | 38 | 390 |
| 0.1 | 1.2 | 11 | | 120 | 0.4 | 4 | 40 | 400 |
| | | | | 125 | | | | 410 |
| | | 12 | | 130 | | | 42 | 420 |
| | | | 1.4 | 135 | | | | 430 |
| | | 13 | | 140 | | | 44 | 440 |
| | | | | 145 | | 4.5 | 45 | 450 |
| | 1.5 | 14 | | 150 | | | 46 | 460 |
| | | | | 155 | | | | 470 |
| 0.12 | 1.6 | 15 | | 160 | | | 48 | 480 |
| | | | | 165 | | | | 490 |
| | | 16 | | 170 | 0.5 | 5 | 50 | 500 |
| | | | 1.8 | 175 | | | 52 | 520 |
| | | 17 | | 180 | | | 53 | 530 |
| | | | | 185 | | 5.5 | 55 | 550 |
| | | 18 | | 190 | | | 56 | 560 |
| | | | | 195 | | | 58 | 580 |
| 0.16 | 2 | 19 | | 200 | 0.6 | 6 | 60 | 600 |
| | | 20 | | 210 | | | 62 | |
| | 2.2 | 21 | | 220 | | | 63 | 630 |
| | | 22 | | 230 | | | 65 | 650 |
| | | 23 | | 240 | | | 67 | 670 |
| | | 24 | | 250 | | | 68 | |
| 0.2 | 2.5 | 25 | | 260 | | 7 | 70 | 700 |
| | | 26 | | 270 | | | 71 | 710 |
| | 2.8 | 27 | | 280 | | | 72 | |
| | | 28 | | 290 | | | 75 | 750 |
| | 3 | 29 | | 300 | | | 78 | |
| 0.25 | | 30 | | 310 | 0.8 | 8 | 80 | 800 |
| | | | | 315 | | | 82 | |
| | 3.2 | 31 | | 320 | | | 85 | 850 |
| | | 32 | | 330 | | | 88 | |
| | | 33 | | 340 | | 9 | 90 | 900 |
| | 3.5 | 34 | | 350 | | | 92 | |
| | | 35 | | 355 | | | 95 | 950 |
| | | 36 | | 360 | | | 98 | |

The standard sizes are a selection of sizes adjusted to standards. They can be used for inter-related dimensions and for such dimensions on which other sizes are dependent. (Tool dimensions). An effort should be made to keep the technical processing simple and economical and to keep the number of gauges, tools, devices instruments, measuring devices etc. to a minimum

The bold numbers are to be preferred.

The following standard sizes are still allowed.

Threads: 0.7 0.9 1.7 2.3 2.6 27 33 39 64 76

Precision mechanic: 6.5 7.5 8.5 etc. upto 14.5

Tool devices: 27 (mill drilling) 31
(accessories for pneumatic tools)

Anti-friction bearings: 37 47 215 225

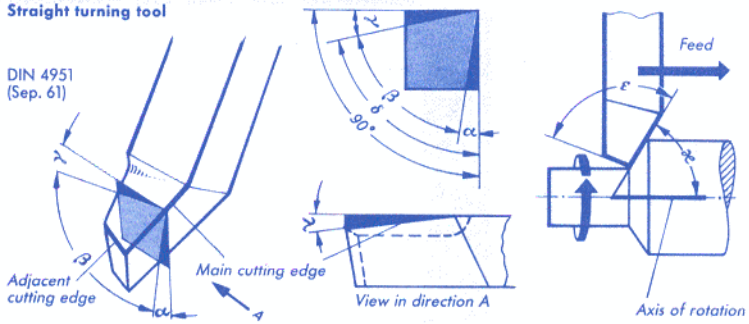
**Separating is the finishing of a solid body by changing its form by local removal of the contents of a material.**

# Separating

## Angle on turning tool

### Straight turning tool

DIN 4951
(Sep. 61)




### Turning tool angle

$\alpha$ = relief angle
$\beta$ = lip angle
$\gamma$ = side rake angle

$\alpha + \beta + \gamma = 90°$

$\delta$ = cutting angle $\quad \delta = \alpha + \beta$

$\varepsilon$ = tip angle
(formed by the main and its adjacent cutting edges)
$\varkappa$ = setting angle
(main cutting edge to rotational axis)
$\lambda$ = tilt angle
(main cutting edge to the horizontal)

Standard values for the angle on turning tools

| For high speed steel and tool steel | | | Used for | with hard metal | | tilt angle |
|---|---|---|---|---|---|---|
| $\alpha$ | $\beta$ | $\gamma$ | | $\alpha$ | $\beta$ | $\lambda$ |
| 6° | 84° | 0° | Hard casting brittle and hard brass and bronze types. | 4°–6° | 80° | 3°–5° |
| 8° | 74° | 8° | Steel and cast-steel over 690 N/mm² strength, hard grey casting, bronze and brass. | 4°–6° | 75°–80° | 3°–5° |
| 8° | 68° | 14° | Steel and steel cast of 490-690 N/mm² strength, grey casting and soft brass | 4°–6° | 75° | 3°–5° |
| 8° | 62° | 20° | Steel and grey casting of 390-490 N/mm² strength | 4°–6° | 65° | 3°–5° |
| 8° | 55° | 27° | Onctile and soft bronzes, softest type of steel. | 4°–6° | 65° | 3°–5° |
| 10° | 40° | 40° | Soft metals and pure aluminium. | 8°–10° | 45°–50° | 5°–10° |

### Setting angle and tip angle for turning tool

| Setting angle $\varkappa$ | tip angle $\varepsilon$ |
|---|---|
| ≈ 45° | ≈ 100° – 110° |
| ≈ 65° | ≈ 90° |
| ≈ 85° | ≈ 80° |

# ISO–Fits for basic hole system

DIN 7154 (Aug. 66)

Blue numbers = deviations on the go side
Red numbers = deviations on the no-go side

Deviations in $\mu m$ (1 $\mu m$ = 0.001 mm)

| | Selection to DIN 7157[1] (Jan. 66) | ISO Symbols | Nominal sizes from 1...3 mm upper deviation | from 1...3 mm lower deviation | from 3...6 mm upper deviation | from 3...6 mm lower deviation | from 6...10 mm upper deviation | from 6...10 mm lower deviation | from 10...18 mm upper deviation | from 10...18 mm lower deviation |
|---|---|---|---|---|---|---|---|---|---|---|
| inner dimensions Holes | | **H 6** | + 6 | 0 | + 8 | 0 | + 9 | 0 | + 11 | 0 |
| outer dimensions Shafts | | n 5 | + 8 | + 4 | + 13 | + 8 | + 16 | + 10 | + 20 | + 12 |
| | 2 | k 6 | + 6 | 0 | + 9 | + 1 | + 10 | + 1 | + 12 | + 1 |
| | 2 | j 6 | + 4 | − 2 | + 6 | − 2 | + 7 | − 2 | + 8 | − 3 |
| | | h 5 | 0 | − 4 | 0 | − 5 | 0 | − 6 | 0 | − 8 |
| inner dimensions Holes | 1 | **H 7** | + 10 | 0 | + 12 | 0 | + 15 | 0 | + 18 | 0 |
| outer dimensions Shafts | 2 | s 6 | + 20 | + 14 | + 27 | + 19 | + 32 | + 23 | + 39 | + 28 |
| | 1 | r 6 | + 16 | + 10 | + 23 | + 15 | + 28 | + 19 | + 34 | + 23 |
| | 1 | n 6 | + 10 | + 4 | + 16 | + 8 | + 19 | + 10 | + 23 | + 12 |
| | | m 6 | + 8 | + 2 | + 12 | + 4 | + 15 | + 6 | + 18 | + 7 |
| | 2 | k 6 | + 6 | 0 | + 9 | + 1 | + 10 | + 1 | + 12 | + 1 |
| | 2 | j 6 | + 4 | − 2 | + 6 | − 2 | + 7 | − 2 | + 8 | − 3 |
| | 1 | h 6 | 0 | − 6 | 0 | − 8 | 0 | − 9 | 0 | − 11 |
| | 2 | g 6 | − 2 | − 8 | − 4 | − 12 | − 5 | − 14 | − 6 | − 17 |
| | 1 | f 7 | − 6 | − 16 | − 10 | − 22 | − 13 | − 28 | − 16 | − 34 |
| inner dimensions Holes | 1 | **H 8** | + 14 | 0 | + 18 | 0 | + 22 | 0 | + 27 | 0 |
| outer dimensions Shafts | 1 | x8, u8[2] | + 34 | + 20 | + 46 | + 28 | + 56 | + 34 | ...14: ...18: | + 67 + 40 + 72 + 45 |
| | 1 | h 9 | 0 | − 25 | 0 | − 30 | 0 | − 36 | 0 | − 43 |
| | 1 | f 7 | − 6 | − 16 | − 10 | − 22 | − 13 | − 28 | − 16 | − 34 |
| | 2 | e 8 | − 14 | − 28 | − 20 | − 38 | − 25 | − 47 | − 32 | − 59 |
| | 2 | d 9 | − 20 | − 45 | − 30 | − 60 | − 40 | − 76 | − 50 | − 93 |
| inner dimensions holes | 2 | **H 11** | + 60 | 0 | + 75 | 0 | + 90 | 0 | + 110 | 0 |
| outer dimensions Shafts | 1 | h 9 | 0 | − 25 | 0 | − 30 | 0 | − 36 | 0 | − 43 |
| | 2 | h 11 | 0 | − 60 | 0 | − 75 | 0 | − 90 | 0 | − 110 |
| | 2 | d 9 | − 20 | − 45 | − 30 | − 60 | − 40 | − 76 | − 50 | − 93 |
| | 2 | c 11 | − 60 | − 120 | − 70 | − 145 | − 80 | − 170 | − 95 | − 205 |
| | 2 | a 11 | − 270 | − 330 | − 270 | − 345 | − 280 | − 370 | − 290 | − 400 |

[1] The system of the fits selected helps to reduce the number of tools, chucks and measuring tools to a minimum

The use of fits is always preferred. Series 1 is the basic series, Series 2 is the supplement to the Series 1. The tolerance range H 11 can be maintained with the usual twist drills, and without post finishing work. The interference fits and transition fits have been essentially derived by taking the basic system as a base. For shafts, the following ranges of tolerance g6, f7, e8, d9, c11 and a11 have been provided which result in the clearance fits with the H-hole system. These ranges of tolerance are now accepted by firms, which prefer basic hole system and derive no advantage from the basic-shaft system. This is because the shafts need to be replaced frequently.

[2] Upto nominal size 24 mm: x 8; above 24 mm: u 8

# ISO-Fits for basic hole system

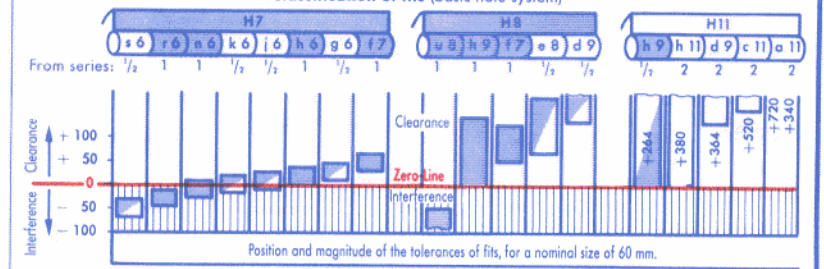
DIN 7154 (Aug. 66)

Deviations in $\mu$m (1 $\mu$ = 0.001 mm)

Nominal size range

| from 18...30 mm | | from 30...50 mm | | from 50...80 mm | | from 80...120 mm | | from 120...180 mm | | from 180...250 mm | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| upper deviat. | lower deviat. | upper deviat. | lower deviat. | upper deviat. | lower deviat. | upper deviat. | lower deviat. | upper deviat. | lower deviat. | upper deviat. | lower deviat. |
| + 13 | 0 | + 16 | 0 | + 19 | 0 | + 22 | 0 | + 25 | 0 | + 29 | 0 |
| + 24 | + 15 | + 28 | + 17 | + 33 | + 20 | + 38 | + 23 | + 45 | + 27 | + 51 | + 31 |
| + 15 | + 2 | + 18 | + 2 | + 21 | + 2 | + 25 | + 3 | + 28 | + 3 | + 33 | + 4 |
| + 9 | − 4 | + 11 | − 5 | + 12 | − 7 | + 13 | − 9 | + 14 | − 11 | + 16 | − 13 |
| 0 | − 9 | 0 | − 11 | 0 | − 13 | 0 | − 15 | 0 | − 18 | 0 | − 20 |
| + 21 | 0 | + 25 | 0 | + 30 | 0 | + 35 | 0 | + 40 | 0 | + 46 | 0 |
| + 48 | + 35 | + 59 | + 43 | ...65: + 72<br>...80: + 78 | + 53<br>+ 59 | ...100: + 93<br>...120: + 101 | + 71<br>+ 79 | ...140: + 117<br>...160: + 125<br>...180: + 133 | + 92<br>+ 100<br>+ 108 | ...200: + 151<br>...225: + 159<br>...250: + 169 | + 122<br>+ 130<br>+ 140 |
| + 41 | + 28 | + 50 | + 34 | ...65: + 60<br>...80: + 62 | + 41<br>+ 43 | ...100: + 73<br>...120: + 76 | + 51<br>+ 54 | ...140: + 88<br>...160: + 90<br>...180: + 93 | + 63<br>+ 65<br>+ 68 | ...200: + 106<br>...225: + 109<br>...250: + 113 | + 77<br>+ 80<br>+ 84 |
| + 28 | + 15 | + 33 | + 17 | + 39 | + 20 | + 45 | + 23 | + 52 | + 27 | + 60 | + 31 |
| + 21 | + 8 | + 25 | + 9 | + 30 | + 11 | + 35 | + 13 | + 40 | + 15 | + 46 | + 17 |
| + 15 | + 2 | + 18 | + 2 | + 21 | + 2 | + 25 | + 3 | + 28 | + 3 | + 33 | + 4 |
| + 9 | − 4 | + 11 | − 5 | + 12 | − 7 | + 13 | − 9 | + 14 | − 11 | + 16 | − 13 |
| 0 | − 13 | 0 | − 16 | 0 | − 19 | 0 | − 22 | 0 | − 25 | 0 | − 29 |
| − 7 | − 20 | − 9 | − 25 | − 10 | − 29 | − 12 | − 34 | − 14 | − 39 | − 15 | − 44 |
| − 20 | − 41 | − 25 | − 50 | − 30 | − 60 | − 36 | − 71 | − 43 | − 83 | − 50 | − 96 |
| + 33 | 0 | + 39 | 0 | + 46 | 0 | + 54 | 0 | + 63 | 0 | + 72 | 0 |
| ...24: + 87<br>...30: + 81 | + 54<br>+ 48 | ...40: + 99<br>...50: + 109 | + 60<br>+ 70 | ...65: + 133<br>...80: + 148 | + 87<br>+ 102 | ...100: + 178<br>...120: + 198 | + 124<br>+ 144 | ...140: + 233<br>...160: + 253<br>...180: + 273 | + 170<br>+ 190<br>+ 210 | ...200: + 308<br>...225: + 330<br>...250: + 356 | + 236<br>+ 258<br>+ 284 |
| 0 | − 52 | 0 | − 62 | 0 | − 74 | 0 | − 87 | 0 | − 100 | 0 | − 115 |
| − 20 | − 41 | − 25 | − 50 | − 30 | − 60 | − 36 | − 71 | − 43 | − 83 | − 50 | − 96 |
| − 40 | − 73 | − 50 | − 89 | − 60 | − 106 | − 72 | − 126 | − 85 | − 148 | − 100 | − 172 |
| − 65 | − 117 | − 80 | − 142 | − 100 | − 174 | − 120 | − 207 | − 145 | − 245 | − 170 | − 285 |
| + 130 | 0 | + 160 | 0 | + 190 | 0 | + 220 | 0 | + 250 | 0 | + 290 | 0 |
| 0 | − 52 | 0 | − 62 | 0 | − 74 | 0 | − 87 | 0 | − 100 | 0 | − 115 |
| 0 | − 130 | 0 | − 160 | 0 | − 190 | 0 | − 220 | 0 | − 250 | 0 | − 290 |
| − 65 | − 117 | − 80 | − 142 | − 100 | − 174 | − 120 | − 207 | − 145 | − 245 | − 170 | − 285 |
| 110 | − 240 | ...40: − 120<br>...50: − 130 | − 280<br>− 290 | ...65: − 140<br>...80: − 150 | − 330<br>− 340 | ...100: − 170<br>...120: − 180 | − 390<br>− 400 | ...140: − 200<br>...160: − 210 | − 450<br>− 460 | ...200: − 240<br>...225: − 260 | − 530<br>− 550 |
| − 300 | − 430 | ...40: − 310<br>...50: − 320 | − 470<br>− 480 | ...65: − 340<br>...80: − 360 | − 530<br>− 550 | ...100: − 380<br>...120: − 410 | − 600<br>− 630 | ...140: − 460<br>...160: − 520 | − 710<br>− 770 | ...200: − 660<br>...225: − 740 | − 950<br>− 1030 |

## Classification of fits (basic hole system)



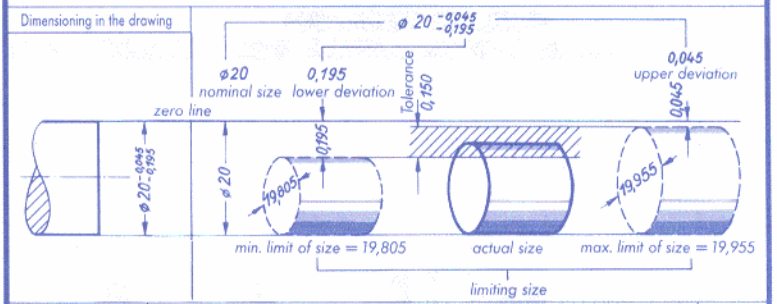

Position and magnitude of the tolerances of fits, for a nominal size of 60 mm.

Tolerance of fit: variation of clearance or interference between the mating parts.

# ISO-Fits

DIN 7182 (Oct. 71)

## Basic principles

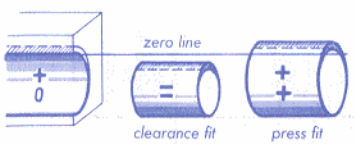



| Terms | Explanation | Symbol |
|---|---|---|
| Nominal size | Design size, to which the deviations relate lays firmly the zero line | $N$ |
| Actual size | The size is determined by taking measurement at one place of the wispiece | $I$ |
| Limiting size | Two sizes, between which the actual size must lie | |
| Max. limit of size | The greater of the two limiting sizes | $G$ |
| Min. limit of size | The smaller of the two limiting sizes | $K$ |
| Deviation | Algebraical difference between a limiting size and the nominal size | $A$ |
| Upper deviation | Algebraical difference between the maximum limit of size and the nominal size | $A_o$ |
| Lower deviation | Algebraical difference between the minimum limit of size and the nominal size | $A_u$ |
| Tolerance | Difference between the maximum and minimum limits of size | $T$ |
| Fit | Relation between the tolerance zones of the matching parts | |
| Clearance | Difference between the sizes of the bore (hole) and the shaft, if the size of the hole is larger | $S$ |
| Max. clearance | Clearance as a result of the difference between the maximum limit of size of the hole and the minimum limit of size of the shaft | $S_g$ |
| Min. clearance | Clearance as a result of the difference between the minimum limit of size of the hole and the maximum limit of size of the shaft | $S_k$ |
| Interference | Difference between the sizes of the hole and the shaft when the hole size is smaller | $U$ |
| Maximum Interference | Interference as a result of difference between the min. limit of the size of the hole and the max. limit of the size of shaft. | $U_g$ |
| Minimum Interference | Interference as a result of difference between the max. limit of the size of the hole and the min. limit of the size of the shaft | $U_k$ |

## Basic hole system

If the nominal size of both hole and shaft were the same one would achieve the following

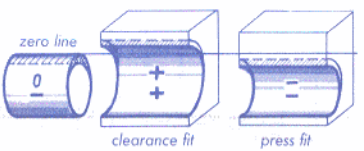
The hole always has the same diameter
The shaft is maintained at a larger or smaller size for the different types of fits




Hole: Minimum deviation = zero
Minimum limit of size = zero line
Application: in machine design, vehicle and locomotive construction

## Basic shaft system

The shaft always has the same diameter
The hole is always maintained at a larger or smaller size for the different types of fits.




Shaft: Upper deviation = zero
Maximum limit of size = zero line
Application: Construction of electric motors, ball-bearings and power transmissions

# ISO-symbols

In the ISO system of fits, symbols (instead of deviations) are added to the nominal sizes.
The deviations can be taken from the table of limits and fits

For example:

deviation according to the table of fits in $\mu$

$1\,\mu = {}^{1}/_{1000}$ mm

$= \varnothing 20^{+21}_{0}$

allowance according to the table of fits in $\mu$

$1\,\mu = {}^{1}/_{1000}$ mm

$= \varnothing 20^{-65}_{-117}$

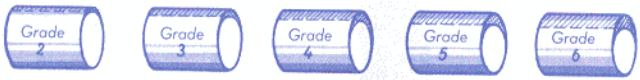
Holes: capital letters are used to designate deviations and are written as super scripts

Shafts: lower case letters are used to designate deviations and are written as subscripts

[1]) The numbers 1...18 represent the magnitude of tolerance. They indicate the quality (grade)

For example:

Tolerances shown exaggerated




| Grade | 1...4 (very fine grade) | 5...11 (fine to coarse) | 12...16 (very coarse) |
|---|---|---|---|
| Application | gauge making | machine building | used in rolling mills |

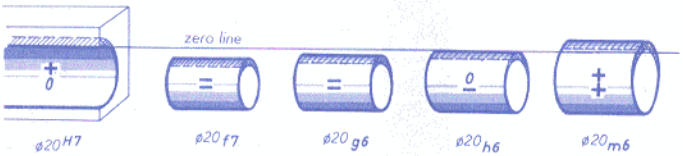
The letters *a*...*z* mark the location of the tolerance along the zero line.
The location determines the kind of fit.

For Example:

**In the case of the basic hole System:**

Hole bears the capital letter *H*

Shafts have different letters for different types of fits to mark the position of the tolerance




Lower deviation = zero minimum limit of size =nominal size

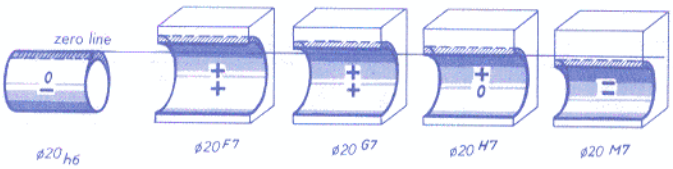
Letters below *h* mark clearance fits

Letters above *p*. press or interference fits

**For basic shaft systems**

Shaft has the letter *h*

Holes have different letters for each kind of fit, and give the position of tolerance along the zero line




Upper deviation = zero maximum limit of size =nominal size

Letters below *H* mark clearance fits

above *P* mark press fits

## ISO–Fits for basic shaft system

DIN 7155 (Aug. 66)

Blue numbers = deviations on the go-side
Red numbers = deviations on the no-go side

Deviations in $\mu$m (1 $\mu$m = 0.001 mm)

| | Selection to DIN 7157 (Jan. 66) | ISO Symbols | Ranges in nominal sizes: from 1…3 mm upper deviation | from 1…3 mm lower deviation | from 3…6 mm upper deviation | from 3…6 mm lower deviation | from 6…10 mm upper deviation | from 6…10 mm lower deviation | from 10…18 mm upper deviation | from 10…18 mm lower deviation |
|---|---|---|---|---|---|---|---|---|---|---|
| Outer dimensions (shafts) | | h 5 | 0 | − 4 | 0 | − 5 | 0 | − 6 | 0 | − 8 |
| Inner dimensions (holes) | | P 6 | − 6 | + 12 | − 9 | − 17 | − 12 | − 21 | − 15 | − 26 |
| | | H 6 | + 6 | 0 | + 8 | 0 | + 9 | 0 | + 11 | 0 |
| Outer dimensions (shafts) | 1 | h 6 | 0 | − 6 | 0 | − 8 | 0 | − 9 | 0 | − 11 |
| Inner dimensions (holes) | | R 7 | − 10 | − 20 | − 11 | − 23 | − 13 | − 28 | − 16 | − 34 |
| | | M 7 | − 2 | − 12 | 0 | − 12 | 0 | − 15 | 0 | − 18 |
| | | K 7 | 0 | − 10 | | | + 5 | − 10 | + 6 | − 12 |
| | 1 | H 7 | + 10 | 0 | + 12 | 0 | + 15 | 0 | + 18 | 0 |
| | 2 | G 7 | + 12 | + 2 | + 16 | + 4 | + 20 | + 5 | + 24 | + 6 |
| | 1 | F 8 | + 20 | + 6 | + 28 | + 10 | + 35 | + 13 | + 43 | + 16 |
| Outer dimensions (shafts) | 1 | h 9 | 0 | − 25 | 0 | − 30 | 0 | − 36 | 0 | − 43 |
| Inner dimensions (holes) | 1 | H 8 | + 14 | 0 | + 18 | 0 | + 22 | 0 | + 27 | 0 |
| | 2 | H 11 | + 60 | 0 | + 75 | 0 | + 90 | 0 | + 110 | 0 |
| | 1 | F 8 | + 20 | + 6 | + 28 | + 10 | + 35 | + 13 | + 43 | + 16 |
| | 1 | E 9 | + 39 | + 14 | + 50 | + 20 | + 61 | + 25 | + 75 | + 32 |
| | 1 | D 10 | + 60 | + 20 | + 78 | + 30 | + 98 | + 40 | + 120 | + 50 |
| | 1 | C 11 | + 120 | + 60 | + 145 | + 70 | + 170 | + 80 | + 205 | + 95 |
| Outer dimensions (shafts) | 2 | h 11 | 0 | − 60 | 0 | − 75 | 0 | − 90 | 0 | − 110 |
| Inner dimensions (holes) | 2 | H 11 | + 60 | 0 | + 75 | 0 | + 90 | 0 | + 110 | 0 |
| | 1 | D 10 | + 60 | + 20 | + 78 | + 30 | + 98 | + 40 | + 120 | + 50 |
| | 1 | C 11 | + 120 | + 60 | + 145 | + 70 | + 170 | + 80 | + 205 | + 95 |
| | 2 | A 11 | + 330 | + 270 | + 345 | + 270 | + 370 | + 280 | + 400 | + 290 |

## Selection of fits

DIN 7157 (Jan. 66)

| | Press fits | Transition fits | Clearance fits | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| From Series 1 | H 8 / x 8 u 8 | H 7 / r 6 | H 7 / n 6 | | H 7 / h 6 | H 8 / h 9 | H 7 / f 7 | H 8 / f 7 | F 8 / h 9 | E 9 / h 9 | D 10 / h 9 | C 11 / h 9 |
| From series 1 and 2 | | | H 7 / k 6 | H 7 / j 6 | H 11 / h 9 | H 7 / g 6 | H 8 / e 8 | H 8 / d 9 | G 7 / h 6 | D 10 / h 11 | C 11 / h 11 | |
| From series 2 | | | | | H 11 / h 11 | H 11 / d 9 | H 11 / c 11 | | A 11 / h 11 | H 11 / a 11 | | |
| | Basic hole system | | | | | | | | Basic shaft system | | | |

# ISO-Fits for basic shaft system

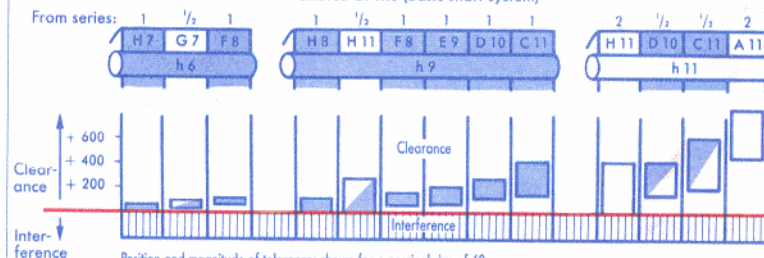
DIN 7155 (Aug. 66)

Deviations in $\mu$m (1 $\mu$ = 0.001 mm)

Range of nominal sizes

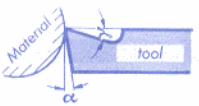
| from 18...30 mm | | from 30...50 mm | | from 50...80 mm | | from 80...120 mm | | from 120...180 mm | | from 180...250 mm | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| upper deviat. | lower deviat. | upper deviat. | lower deviat. | upper deviat. | lower deviat. | upper deviat. | lower deviat. | upper deviat. | lower deviat. | upper deviat. | lower deviat. |
| 0 | − 9 | 0 | − 11 | 0 | − 13 | 0 | − 15 | 0 | − 18 | 0 | − 20 |
| − 18 | − 31 | − 21 | − 37 | − 26 | − 45 | − 30 | − 52 | − 36 | − 61 | − 41 | − 70 |
| + 13 | 0 | + 16 | 0 | + 19 | 0 | + 22 | 0 | + 25 | 0 | + 29 | 0 |
| 0 | − 13 | 0 | − 16 | 0 | − 19 | 0 | − 22 | 0 | − 25 | 0 | − 29 |
| − 20 | − 41 | − 25 | − 50 | ...65: − 30 ...80: − 32 | − 60 − 62 | ...100: − 38 ...120: − 41 | − 73 − 76 | ...140: − 48 ...160: − 50 ...180: − 53 | − 88 − 90 − 93 | ...200: − 60 ...225: − 63 ...250: − 67 | − 106 − 109 − 113 |
| 0 | − 21 | 0 | − 25 | 0 | − 30 | 0 | − 35 | 0 | − 40 | 0 | − 46 |
| + 6 | − 15 | + 7 | − 18 | + 9 | − 21 | + 10 | − 25 | + 12 | − 28 | + 13 | − 33 |
| + 21 | 0 | + 25 | 0 | + 30 | 0 | + 35 | 0 | + 40 | 0 | + 46 | 0 |
| + 28 | + 7 | + 34 | + 9 | + 40 | + 10 | + 47 | + 12 | + 54 | + 14 | + 61 | + 15 |
| + 53 | + 20 | + 64 | + 25 | + 76 | + 30 | + 90 | + 36 | + 106 | + 43 | − 122 | − 50 |
| 0 | − 52 | 0 | − 62 | 0 | − 74 | 0 | − 87 | 0 | − 100 | 0 | − 115 |
| + 33 | 0 | + 39 | 0 | + 46 | 0 | + 54 | 0 | + 63 | 0 | + 72 | 0 |
| + 130 | 0 | + 160 | 0 | + 190 | 0 | + 220 | 0 | + 250 | 0 | + 290 | 0 |
| + 53 | + 20 | + 64 | + 25 | + 76 | + 30 | + 90 | + 36 | + 106 | + 43 | + 122 | + 50 |
| + 92 | + 40 | + 112 | + 50 | + 134 | + 60 | + 159 | + 72 | + 185 | + 85 | + 215 | + 100 |
| + 149 | + 65 | + 180 | + 80 | + 220 | + 100 | + 260 | + 120 | + 305 | + 145 | + 355 | + 170 |
| + 240 | + 110 | ...40: + 280 + 120 ...50: + 290 + 130 | | ...65: + 330 + 140 ...80: + 340 + 150 | | ...100: + 390 + 170 ...120: + 400 + 180 | | ...140: + 450 + 200 ...160: + 460 + 210 ...180: + 480 + 230 | | ...200: + 530 + 240 ...225: + 550 + 260 ...250: + 570 + 280 | |
| 0 | − 130 | 0 | − 160 | 0 | − 190 | 0 | − 220 | 0 | − 250 | 0 | − 290 |
| + 130 | 0 | + 160 | 0 | + 190 | 0 | + 220 | 0 | + 250 | 0 | + 290 | 0 |
| + 149 | + 65 | + 180 | + 80 | + 220 | + 100 | + 260 | + 120 | + 305 | + 145 | + 355 | + 170 |
| + 240 | + 110 | ...40: + 280 + 120 ...50: + 290 + 130 | | ...65: + 330 + 140 ...80: + 340 + 150 | | ...100: + 390 + 170 ...120: + 400 + 180 | | ...140: + 450 + 200 ...160: + 460 + 210 ...180: + 480 + 230 | | ...200: + 530 + 240 ...225: + 550 + 260 ...250: + 570 + 280 | |
| + 430 | + 300 | ...40: + 470 + 310 ...50: + 480 + 320 | | ...65: + 530 + 340 ...80: + 550 + 360 | | ...100: + 600 + 380 ...120: + 630 + 410 | | ...140: + 710 + 460 ...160: + 770 + 520 ...180: + 830 + 580 | | ...200: + 950 + 660 ...225: + 1030 + 740 ...250: + 1110 + 820 | |

**Choice of fits** (basic shaft system)




Position and magnitude of tolerances shown for a nominal size of 60 mm
tolerance magnitude = possible variation in the clearance or the interference meeting between the pairs

## Correct values for cutting speeds – cutting angle – specific cutting force




Values applicable to dry cutting in the case of: Extract from AWF-158
High speed steel tools for cutting speed $v_{60}$ (tool life 60 min.)
Hard alloy tools for cutting speed $v_{240}$ (tool life 240 min.)
Setting angle $\varkappa = 45°$, tip angle = 90°, tilt angle = 0...8°
for light alloys, synthetic and plastic materials = 5...10°.
The current values apply for depth of cut upto 5 mm, above 5 mm depth of cut reduce the cutting speed by 10 - 20 %.

For the specific cutting force values: a cutting depth of 2...10 times that of the feed is applicable

| Material | 1) tool | Side clear ∢ α° | Side rake ∢ γ° | Feed in mm/rev. 0.1 | 0.2 | 0.4 | 0.8 | 1.6 | 3.2 | Feed in mm/rev. 0.1 | 0.2 | 0.4 | 0.8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | cutting speed in m/mm | | | | | | specific cutting force ks N/mm² of chip section | | | |
| **Plain steel** St 34, St 37, St 42 | SS | 8 | 14 | | 60 | 45 | 34 | 25 | 19 | 3600 | 2600 | 1900 | 1360 |
| | $S_1$ | 5 | 10 | 280 | 236 | 200 | 170 | * 67 | * 56 | | | | |
| St 50, St 60 | SS | 8 | 14 | | 44 | 32 | 24 | 18 | 14 | 4100 | 2950 | 2150 | 1540 |
| | $S_1$ | 5 | 10 | 240 | 205 | 175 | 145 | * 50 | * 42 | | | | |
| St 70 | SS | 8 | 14 | | 32 | 24 | 18 | 13 | 10 | 4400 | 3150 | 2300 | 1640 |
| | $S_1$ | 5 | 10 | 200 | 170 | 132 | 106 | * 34 | * 27 | | | | |
| **Cast steel** | SS | 8 | 10 | | 34 | 25 | 19 | 14 | 11 | 3600 | 2600 | 1900 | 1360 |
| | $S_1$ | 5 | 6 | 118 | 100 | 85 | 71 | * 24 | * 20 | | | | |
| **Alloy steel** | SS | 8 | 10 | | 24 | 17 | 12 | 8.5 | (6) | 5000 | 3600 | 2600 | 1850 |
| | $S_1$ | 5 | 6 | 150 | 118 | 95 | 75 | * 24 | * 20 | | | | |
| Mn-Steel, Cr-Ni-Steel, Cr-Mo-Steel | SS | 8 | 6 | | 16 | 11 | 8 | (5.6) | | 5300 | 3800 | 2750 | 2000 |
| | $S_1$ | 5 | 6 | 95 | 75 | 60 | 50 | * 16 | * 13 | | | | |
| and other steel alloys | SS | 8 | 6 | | 9.5 | 6 | | | | 5700 | 4100 | 3000 | 2150 |
| | $S_1$ | 5 | 6 | 60 | 48 | 38 | 32 | * 10 | * 8 | | | | |
| **Tool steel** | SS | 8 | 6 | | | | | | | 5700 | 4100 | 3000 | 2150 |
| | $S_1$ | 5 | 6 | 50 | 40 | 32 | 27 | * 8.5 | * 6.7 | | | | |
| **Manganese steel** | SS | | | | | | | | | 6600 | 4800 | 3500 | 2520 |
| | $S_1$ | 5 | 6 | 40 | 32 | 25 | 20 | * 6.7 | * 5.3 | | | | |
| **Cast iron** GG-10, GG-15 | SS | 8 | 0 | | 48 | 27 | 18 | 14 | 9.5 | 1900 | 1360 | 1000 | 720 |
| | $G_1$ | 5 | 0 | 140 | 118 | 95 | 80 | 67 | | | | | |
| GG-20, GG-25 | SS | 8 | 0 | | 32 | 18 | 13 | 9.5 | 6.3 | 2900 | 2080 | 1500 | 1080 |
| | $H_1$ | 5 | 0 | 106 | 90 | 75 | 63 | 53 | | | | | |
| Malleable cast iron | SS | 8 | 10 | | 43 | 28 | 20 | 13 | 9 | 2400 | 1750 | 1250 | 920 |
| | $S_1$ | 5 | 10 | 106 | 90 | 75 | 63 | 53 | | | | | |
| **Copper alloys** Brass | SS | 8 | 0 | | 125 | 85 | 56 | 36 | | 1600 | 1150 | 850 | 600 |
| | $G_1$ | 5 | 6 | 600 | 530 | 450 | 400 | 355 | | | | | |
| Red brass | SS | 8 | 0 | | 85 | 63 | 48 | 34 | 24 | 1400 | 1000 | 700 | 520 |
| | $G_1$ | 5 | 6 | 500 | 450 | 375 | 335 | 300 | | | | | |
| Cast bronze | SS | 8 | 0 | | 63 | 53 | 43 | 36 | 28 | 3400 | 2450 | 1800 | 1280 |
| | $G_1$ | 5 | 6 | 355 | 280 | 236 | 200 | 180 | | | | | |
| **Light alloys** Pure aluminium | SS | 12 | 30 | 400 | 300 | 200 | 118 | 75 | | 1050 | 760 | 550 | 400 |
| | $G_1$ | 12 | 30 | 1320 | 1120 | 950 | 850 | 710 | | | | | |
| Al-alloys (11...13 % Si) | SS | 12 | 18 | 100 | 67 | 45 | 30 | | | 1400 | 1000 | 700 | 520 |
| | $G_1$ | 12 | 18 | 224 | 190 | 160 | 140 | 118 | | | | | |
| Piston alloys G Al-Si (11...13 % Si) | SS | 12 | 14 | | | | | | | 1250 | 900 | 650 | 480 |
| | $G_1$ | 12 | 14 | 25 | 22 | 20 | 18 | 17 | | | | | |
| Magnesium alloys | SS | 8 | 6 | 1000 | 900 | 800 | 750 | 710 | | 580 | 420 | 300 | 220 |
| | $G_1$ | 5 | 6 | 1800 | 1500 | 1250 | 1060 | 900 | | | | | |
| **Synth. & moulded mat.** hard rubber | SS | 12 | 10 | | | | | | | 480 | 350 | 250 | 180 |
| | $G_1$ | 12 | 10 | 300 | 280 | 250 | 224 | 200 | | | | | |
| Moulded materials, Novotex, Pertinax | SS | 12 | 14 | | | | | | | 480 | 350 | 250 | 180 |
| | $G_1$ | 12 | 14 | 280 | 212 | 170 | 132 | 100 | | | | | |

1) SS = High speed steel: $S_1$, $S_3$, $H_1$, $G_1$ = Hard alloy as per DIN  * with $S_3$.

## Cutting power  Drive power

Chip section $S = a \cdot s$ in mm²
Chip volume $V = a \cdot s \cdot v$ in cm³/min
Cutting force $F = a \cdot s \cdot ks$ in N/mm²
Output of the deck motor $P = \frac{a \cdot s \cdot ks \cdot v}{60 \cdot \eta}$ in W

$a$ = depth of cut in mm
$s$ = Feed in mm/rev
$v$ = cutting speed in m/min
$ks$ = specific cutting force in N/mm²
$\eta$ = efficiency

Example: Material St 37, $a = 4$ mm, $s = 0.4$ mm/rev, $ks = 1900$ N/mm², $v = 45$ m/min. $\eta = 0.75$

Find the required amount of drive power [kW] $P = \frac{4 \cdot 0.4 \cdot 1900 \cdot 45}{60 \cdot 0.75} = 3030$ W $\approx 3$ kW

### Chip section for the drive power $P = 1$ kW

| Cutting speed $v$ m/min | Specific cutting force $ks$ in N/mm² | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6600 | 5700 | 5000 | 4800 | 4100 | 3600 | 3000 | 2600 | 2150 | 2000 | 1900 | 1600 | 1400 | 1250 | 1000 | 700 | 500 | 350 |
| | Chip section $S$ in mm² for $P = 1$ kW ($\eta = 0.75$) | | | | | | | | | | | | | | | | | |
| 5 | 1.39 | 1.61 | 1.83 | 1.91 | 2.23 | 2.55 | 3.06 | 3.53 | 4.27 | 4.59 | 4.83 | 5.73 | 6.55 | 7.34 | 9.18 | 13.11 | 18.36 | 26.22 |
| 6 | 1.15 | 1.34 | 1.53 | 1.59 | 1.86 | 2.12 | 2.53 | 2.94 | 3.55 | 3.82 | 4.02 | 4.78 | 5.46 | 6.12 | 7.65 | 10.92 | 15.30 | 21.85 |
| 8 | 0.87 | 1.00 | 1.14 | 1.19 | 1.39 | 1.59 | 1.91 | 2.20 | 2.66 | 2.86 | 3.02 | 3.56 | 4.09 | 4.59 | 5.73 | 8.19 | 11.47 | 16.39 |
| 10 | 0.69 | 0.80 | 0.91 | 0.95 | 1.11 | 1.27 | 1.53 | 1.76 | 2.13 | 2.29 | 2.41 | 2.86 | 3.27 | 3.67 | 4.59 | 6.55 | 9.18 | 13.11 |
| 13 | 0.53 | 0.61 | 0.70 | 0.73 | 0.83 | 0.98 | 1.17 | 1.53 | 1.64 | 1.76 | 1.85 | 2.20 | 2.52 | 2.82 | 3.53 | 5.04 | 7.06 | 10.08 |
| 14 | 0.49 | 0.57 | 0.65 | 0.68 | 0.79 | 0.91 | 1.09 | 1.26 | 1.52 | 1.64 | 1.72 | 2.04 | 2.36 | 2.62 | 3.27 | 4.68 | 6.55 | 9.36 |
| 15 | 0.46 | 0.53 | 0.61 | 0.63 | 0.74 | 0.85 | 1.02 | 1.17 | 1.42 | 1.53 | 1.61 | 1.91 | 2.18 | 2.44 | 3.06 | 4.37 | 6.12 | 8.74 |
| 18 | 0.38 | 0.44 | 0.51 | 0.53 | 0.62 | 0.70 | 0.85 | 0.98 | 1.18 | 1.26 | 1.34 | 1.59 | 1.82 | 2.04 | 2.55 | 3.64 | 5.10 | 7.28 |
| 20 | 0.34 | 0.40 | 0.45 | 0.47 | 0.55 | 0.63 | 0.76 | 0.88 | 1.06 | 1.14 | 1.20 | 1.43 | 1.63 | 1.83 | 2.29 | 3.27 | 4.59 | 6.55 |
| 24 | 0.29 | 0.33 | 0.38 | 0.39 | 0.46 | 0.53 | 0.63 | 0.73 | 0.88 | 0.95 | 1.00 | 1.19 | 1.36 | 1.53 | 1.91 | 2.18 | 3.82 | 5.46 |
| 25 | 0.27 | 0.32 | 0.36 | 0.38 | 0.44 | 0.51 | 0.61 | 0.70 | 0.85 | 0.91 | 0.98 | 1.14 | 1.31 | 1.46 | 1.83 | 2.62 | 3.67 | 5.24 |
| 27 | 0.25 | 0.29 | 0.34 | 0.35 | 0.41 | 0.47 | 0.57 | 0.65 | 0.79 | 0.85 | 0.89 | 1.06 | 1.21 | 1.36 | 1.70 | 2.42 | 3.40 | 4.85 |
| 32 | 0.21 | 0.25 | 0.28 | 0.29 | 0.35 | 0.39 | 0.47 | 0.55 | 0.66 | 0.71 | 0.75 | 0.89 | 1.02 | 1.14 | 1.43 | 2.04 | 2.86 | 4.09 |
| 34 | 0.20 | 0.23 | 0.26 | 0.28 | 0.33 | 0.37 | 0.45 | 0.52 | 0.62 | 0.67 | 0.71 | 0.84 | 0.96 | 1.08 | 1.35 | 1.92 | 2.70 | 3.85 |
| 40 | 0.17 | 0.20 | 0.22 | 0.23 | 0.27 | 0.31 | 0.38 | 0.44 | 0.53 | 0.57 | 0.60 | 0.71 | 0.81 | 0.91 | 1.14 | 1.63 | 2.29 | 3.27 |
| 45 | 0.15 | 0.18 | 0.20 | 0.21 | 0.25 | 0.28 | 0.34 | 0.38 | 0.47 | 0.51 | 0.53 | 0.63 | 0.72 | 0.81. | 1.02 | 1.48 | 2.04 | 2.91 |
| 50 | 0.13 | 0.16 | 0.18 | 0.19 | 0.22 | 0.25 | 0.30 | 0.35 | 0.42 | 0.46 | 0.49 | 0.57 | 0.65 | 0.73 | 0.91 | 1.31 | 1.83 | 2.62 |
| 53 | | 0.15 | 0.17 | 0.18 | 0.21 | 0.24 | 0.28 | 0.33 | 0.40 | 0.43 | 0.46 | 0.54 | 0.61 | 0.69 | 0.86 | 1.23 | 1.73 | 2.47 |
| 60 | | 0.13 | 0.15 | 0.16 | 0.18 | 0.21 | 0.25 | 0.29 | 0.35 | 0.38 | 0.40 | 0.47 | 0.54 | 0.61 | 0.76 | 1.09 | 1.53 | 2.18 |
| 63 | | 0.12 | 0.14 | 0.15 | 0.17 | 0.20 | 0.24 | 0.28 | 0.33 | 0.36 | 0.38 | 0.45 | 0.52 | 0.58 | 0.73 | 1.04 | 1.45 | 2.08 |
| 67 | | 0.11 | 0.13 | 0.14 | 0.16 | 0.19 | 0.22 | 0.26 | 0.31 | 0.34 | 0.36 | 0.42 | 0.49 | 0.54 | 0.68 | 0.97 | 1.37 | 1.95 |
| 75 | | 0.10 | 0.12 | 0.12 | 0.14 | 0.17 | 0.20 | 0.23 | 0.28 | 0.30 | 0.32 | 0.38 | 0.42 | 0.48 | 0.60 | 0.87 | 1.22 | 1.74 |
| 85 | | | 0.10 | 0.11 | 0.13 | 0.15 | 0.18 | 0.20 | 0.25 | 0.27 | 0.28 | 0.33 | 0.38 | 0.43 | 0.54 | 0.77 | 1.08 | 1.54 |
| 95 | | | 0.09 | 0.10 | 0.11 | 0.13 | 0.16 | 0.18 | 0.22 | 0.24 | 0.25 | 0.30 | 0.34 | 0.38 | 0.48 | 0.69 | 0.96 | 1.37 |
| 100 | | | 0.09 | 0.09 | 0.11 | 0.13 | 0.15 | 0.17 | 0.21 | 0.23 | 0.24 | 0.28 | 0.32 | 0.36 | 0.45 | 0.65 | 0.91 | 1.31 |
| 106 | | | 0.08 | 0.09 | 0.10 | 0.12 | 0.14 | 0.16 | 0.20 | 0.21 | 0.22 | 0.27 | 0.30 | 0.34 | 0.43 | 0.61 | 0.86 | 1.23 |
| 118 | | | 0.07 | 0.08 | 0.09 | 0.10 | 0.13 | 0.15 | 0.18 | 0.19 | 0.20 | 0.24 | 0.28 | 0.31 | 0.38 | 0.55 | 0.78 | 1.11 |
| 150 | **Example:** | | | 0.06 | 0.07 | 0.08 | 0.10 | 0.11 | 0.14 | 0.15 | 0.16 | 0.19 | 0.21 | 0.24 | 0.30 | 0.43 | 0.61 | 0.87 |
| 170 | $P = ?$ kW | | | 0.05 | 0.06 | 0.07 | 0.09 | 0.10 | 0.12 | 0.13 | 0.14 | 0.16 | 0.19 | 0.21 | 0.27 | 0.38 | 0.54 | 0.77 |
| 200 | St 60 | | | 0.04 | 0.05 | 0.06 | 0.07 | 0.08 | 0.10 | 0.11 | 0.12 | 0.14 | 0.16 | 0.18 | 0.22 | 0.32 | 0.45 | 0.65 |
| 224 | $s = 0.4$ mm/rev. | | | | 0.05 | 0.05 | 0.06 | 0.08 | 0.09 | 0.10 | 0.11 | 0.13 | 0.14 | 0.16 | 0.20 | 0.29 | 0.40 | 0.58 |
| 236 | $a = 4$ mm | | | | 0.04 | 0.05 | 0.06 | 0.07 | 0.08 | 0.09 | 0.10 | 0.12 | 0.13 | 0.15 | 0.19 | 0.27 | 0.38 | 0.55 |
| 250 | $v = 32$ m/min | | | | 0.04 | 0.04 | 0.05 | 0.07 | 0.08 | 0.08 | 0.09 | 0.11 | 0.13 | 0.14 | 0.18 | 0.26 | 0.36 | 0.52 |
| 280 | if $P = 1$ kW then $S = 0.66$ mm² (table value) | | | | 0.03 | 0.04 | 0.05 | 0.06 | 0.07 | 0.08 | 0.08 | 0.10 | 0.11 | 0.13 | 0.16 | 0.23 | 0.32 | 0.46 |
| 300 | if $S = 0.4 \cdot 4 = 1.6$ mm² | | | | | 0.03 | 0.05 | 0.05 | 0.07 | 0.07 | 0.08 | 0.09 | 0.10 | 0.12 | 0.15 | 0.21 | 0.30 | 0.43 |
| 400 | then $P = \frac{1 \cdot 1.6}{0.66} = 2.4$ kW | | | | | 0.03 | 0.04 | 0.04 | 0.05 | 0.05 | 0.06 | 0.07 | 0.08 | 0.09 | 0.11 | 0.16 | 0.22 | 0.32 |
| 500 | Chip section $S = ?$ | | | | | | 0.03 | 0.03 | 0.04 | 0.04 | 0.04 | 0.05 | 0.06 | 0.07 | 0.09 | 0.13 | 0.18 | 0.26 |
| 600 | Gs, $v = 5$ m/min | | | | | | 0.02 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.05 | 0.06 | 0.07 | 0.10 | 0.15 | 0.21 |
| 800 | $ks = 1900$ N/mm² (table value), $P = 2$ kW | | | | | | | | 0.02 | 0.02 | 0.03 | 0.03 | 0.04 | 0.04 | 0.05 | 0.08 | 0.11 | 0.16 |
| 1000 | if $P = 1$ kW, then $S = 0.98$ mm² (table value) | | | | | | | | | | | | | | | 0.06 | 0.09 | 0.13 |
| 1500 | For $s = 0.4$ mm/rev it is possible that | | | | | | | | | | | | | | | 0.04 | 0.06 | 0.09 |
| | if $P = 2$ kW, then $S = 0.98 \cdot 2$ mm² $= 1.04$ mm² | | | | | | | | | | | | | | | | | |
| | $\alpha = 1.04 : 0.4 = 4.9$ mm. | | | | | | | | | | | | | | | | | |

## Revolutions per minute $n$ – cutting speed $v$ – diameter $d$

| Ø in mm $d$ | cutting speed $v$ in m/min: 8 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 50 | 80 | 100 | 150 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Revolutions per minute | | | | | | | | | | | |
| 10 | **255** | **318** | 478 | **637** | **796** | 956 | 1125 | 1274 | 1590 | 2550 | 3180 | 4800 |
| 11 | **231** | **289** | 434 | **580** | 724 | 868 | **1013** | 1157 | **1445** | 2310 | **2890** | 4350 |
| 12 | **212** | 265 | **398** | 531 | 663 | **796** | 928 | 1060 | 1325 | 2130 | 2660 | **4000** |
| 14 | **182** | **228** | 341 | **455** | **568** | 682 | **796** | **910** | 1136 | 1820 | 2280 | 3410 |
| 16 | **159** | **199** | 298 | **398** | **497** | 597 | 695 | **796** | **995** | 1590 | **1990** | 2980 |
| 18 | **142** | **177** | 265 | **354** | **443** | 530 | **620** | **708** | **885** | **1420** | 1770 | 2660 |
| 20 | **128** | **159** | 239 | **319** | **398** | 478 | **558** | **637** | **795** | 1270 | 1590 | 2390 |
| 22 | **116** | **145** | 217 | **290** | **362** | 434 | **506** | **579** | **723** | 1150 | **1450** | 2170 |
| 25 | **102** | **128** | 192 | **255** | **319** | 383 | 446 | **510** | 638 | **1020** | 1280 | 1910 |
| 28 | 91 | **114** | 171 | **227** | **284** | 341 | **398** | **455** | **568** | **910** | 1140 | 1710 |
| 32 | 80 | **100** | **149** | **199** | **249** | 298 | 348 | **398** | **498** | **800** | **1000** | **1490** |
| 36 | 71 | **89** | 133 | **177** | 221 | 265 | 310 | **354** | **442** | **710** | **890** | 1330 |
| 40 | **64** | 80 | 119 | **159** | **199** | 239 | **278** | **318** | **393** | **640** | **800** | 1200 |
| 45 | 57 | 71 | 106 | **142** | **177** | 214 | **248** | **283** | **354** | **570** | **710** | 1060 |
| 50 | 51 | **64** | 96 | **127** | **159** | 191 | **223** | **255** | **318** | **510** | **640** | 950 |
| 55 | 46 | 58 | 87 | **116** | **145** | 174 | **203** | 231 | 298 | **460** | **580** | 870 |
| 60 | 43 | 53 | 80 | 106 | 133 | **159** | **186** | 212 | 265 | 420 | 530 | **800** |
| 70 | 36 | **46** | 68 | **91** | 114 | 136 | 169 | **182** | **227** | **360** | **450** | 680 |
| 80 | **32** | 40 | 60 | 80 | **100** | 119 | **139** | **159** | **199** | **320** | **400** | 600 |
| 90 | 28 | 35 | 53 | 71 | **89** | 106 | **124** | **142** | **177** | **285** | **355** | 530 |
| 100 | 26 | **32** | 48 | **64** | 80 | 96 | **111** | **127** | **159** | **255** | **320** | 480 |
| 110 | **23** | 29 | 43 | 58 | 73 | 87 | **101** | **116** | **145** | **232** | **290** | 435 |
| 125 | 20 | 26 | 38 | 51 | **64** | 76 | **89** | **102** | **127** | **200** | **255** | 380 |
| 140 | 18 | **23** | 34 | **46** | 57 | 68 | 80 | **91** | **114** | **180** | **228** | 340 |
| 160 | **16** | 20 | 30 | 40 | 50 | 60 | 70 | 80 | **100** | **160** | **200** | 300 |
| 180 | 14 | 17 | 27 | 35 | **44** | 53 | 62 | 71 | **88** | **140** | 175 | 265 |
| 200 | 12 | **16** | 24 | **32** | 40 | 48 | 56 | **64** | 80 | **125** | **160** | 240 |
| 220 | **11.6** | 14 | **22** | 29 | 36 | 43 | 50 | 57 | 71 | **114** | **143** | 210 |
| 250 | 10.2 | 12.7 | 19 | 25 | **32** | 38 | **44** | 51 | **64** | **100** | **125** | **190** |
| 275 | 9.2 | **11.6** | 17 | **23** | 29 | 35 | 40 | 47 | 58 | **93** | **115** | **175** |
| 300 | 8.5 | 10.6 | **16** | 21 | 26 | **32** | 37 | 43 | 53 | 85 | 105 | **160** |
| 350 | 7.2 | 9.1 | 14 | 18 | **22** | 28 | **32** | 36 | **45** | 73 | **91** | 135 |
| 400 | 6.3 | 7.9 | 12 | **16** | 20 | 24 | 28 | **32** | 40 | **64** | 80 | 120 |

Bold numbers lie within the limiting values for load cycles for machine tools

## On-load speeds for machine tools

DIN 804 (Nov. 66)

Revolutions per minute 1/min

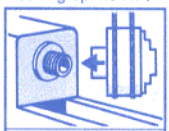
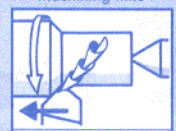
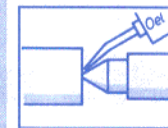
| Basic series R 20 | Series 2 | Series 3 | | | Limiting value Series 1 −2% | Limiting value Series 1 +6% | Basic series R 20 | Series 2 | Series 3 | | | Limiting value Series 1 −2% | Limiting value Series 1 +6% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 100 | | | | | 98 | 106 | 315 | | 31.5 | | | 310 | 335 |
| 112 | 112 | 11.2 | | | 110 | 119 | 355 | 355 | | 355 | | 348 | 376 |
| 125 | | | 125 | | 123 | 133 | 400 | | | | 4000 | 390 | 422 |
| 140 | 140 | | | 1400 | 138 | 150 | 450 | 450 | 45 | | | 438 | 473 |
| 160 | | 16 | | | 155 | 168 | 500 | | | 500 | | 491 | 531 |
| 180 | 180 | | 180 | | 174 | 188 | 560 | 560 | | | 5600 | 551 | 596 |
| 200 | | | | 2000 | 196 | 212 | 630 | | 63 | | | 618 | 669 |
| 224 | 224 | 22.4 | | | 219 | 237 | 710 | 710 | | 710 | | 694 | 750 |
| 250 | | | 250 | | 246 | 266 | 800 | | | | 8000 | 778 | 842 |
| 280 | 280 | | | 2800 | 276 | 299 | 900 | 900 | 90 | | | 873 | 945 |

The series can be extended further by multiplication or division by 10 and 100

# Calculating the basic operational time

Suggestions for determining the operational time are based on investigations made by REFA (Association for Analysing Work Time and Process Planning). On the basis of this, the processing time is composed of the following

**Basic time**

| Setting-up the time | machining time | un-productive time | Allowance |
|---|---|---|---|
|  |  | |  |
| Setting-up the machine getting tools reading instructions | Machining time (cutting time = turning time) | Gripping and unclamping setting the cutting tools and measuring | Lubrication operational disturbances |

## Longitudinal turning

### r.p.m. $n$ known

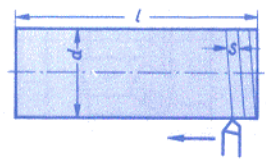
$l$ = length turned in mm
$s$ = feed in mm/rev.
$n$ = r.p.m.

Feed per minute
$s^1 = s \cdot n$

$$t_h = \frac{l}{s \cdot n} \text{ in min}$$

**Example:**
$l$ = 600 mm
$s$ = 0.5 mm/rev.
$n$ = 50 r.p.m.

$$t_h = \frac{600}{0.5 \text{ mm/rev.} \cdot 50 \text{ r.p.m.}}$$
$$= 24 \text{ min}$$




$$\text{Machining time} = \frac{\text{length turned}}{\text{feed/min}}$$

The calculated rotations do not always match with the actual one

### r.p.m. $n$ not known

$d$ = diameter in m
$v$ = cutting speed in m/min.
$s$ = feed in mm/rev.
$l$ = length in mm

$$n = \frac{v}{\pi \cdot d}$$

$$t_h = \frac{l \cdot \pi \cdot d}{s \cdot v} \text{ in min}$$

**Example:**
$d$ = 0.125 m
$v$ = 20 m/min
$s$ = 0.5 mm/rev.
$l$ = 600 mm

$$t_h = \frac{600 \text{ mm} \cdot 3.14 \cdot 0.125 \text{ m}}{0.5 \text{ mm/rev.} \cdot 20 \text{ m/min}}$$
$$= 23.5 \text{ min}$$

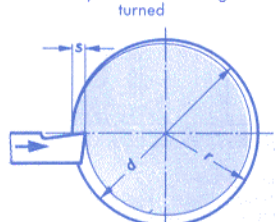
## Facing

$$n = \frac{v}{\pi \cdot d}$$

$$t_h = \frac{r}{s \cdot n}$$

When the cutting speed remains constant, the average rotation speed must be set for $n$

In facing, the radius $r$ corresponds with the length turned




**Example:**
$d$ = 0.250 m
$v$ = 20 m/min
$s$ = 0.5 mm/rev.

$$n = \frac{v}{\pi \cdot d} = \frac{20 \text{ m/min}}{3.14 \cdot 0.25 \text{ m}}$$
$$= 25 \text{ r.p.m.}$$

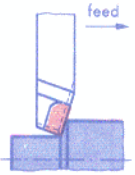
$$t_h = \frac{r}{s \cdot n} = \frac{125 \text{ mm}}{0.5 \text{ mm} \cdot 25 \text{ r.p.m.}}$$
$$= 10 \text{ min}$$

# Turning tool

with hard metal cutting plates

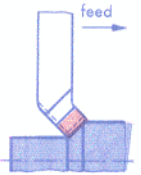
DIN 4971 – 4978
4980, 4981 (Aug. 63)

ISO 1
DIN 4971



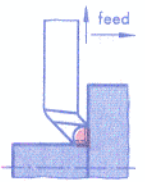

absolutely vertical chisel

ISO 2
DIN 4972



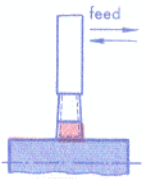

chisel bent towards right

ISO 3
DIN 4978



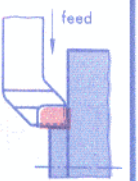

tool for corner work

ISO 4
DIN 4976



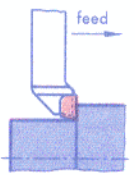

broad chisel

ISO 5
DIN 4977



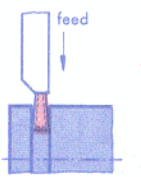

face chisel

ISO 6
DIN 4974



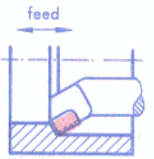

preset towards right cutting

ISO 7
DIN 4981



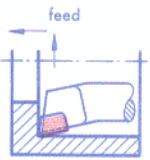

cutting-off chisel

ISO 8
DIN 4973



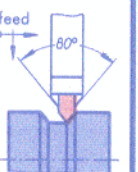

inside chisel

ISO 9
DIN 4974




internal for corner work

DIN 4971



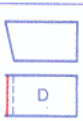

pointed chisel

## Turning tool – cross-section of shank

| | Height h | Width b | Cutting plate[1] left | Cutting plate[1] right |
|---|---|---|---|---|
| ISO 1 | 10 | 10 | B 8[2] | A 8 |
| | 12 | 12 | B 10 | A 10 |
| | 16 | 16 | B 12 | A 12 |
| | 20 | 20 | B 16 | B 16 |
| ISO 2 | 10 | 10 | C 8 | |
| | 12 | 12 | C 10 | |
| | 16 | 16 | C 12 | |
| | 20 | 20 | C 16 | |
| ISO 3 | 16 | 10 | B 8 | A 8 |
| | 20 | 12 | B 10 | A 10 |
| | 25 | 16 | B 12 | A 12 |
| | 32 | 20 | B 16 | A 16 |
| ISO 4 | 10 | 10 | C 10 | |
| | 12 | 12 | C 12 | |
| | 16 | 16 | C 16 | |
| | 20 | 20 | C 20 | |
| | 20 | 12 | C 12 | |
| | 26 | 16 | C 16 | |
| | 32 | 20 | C 20 | |

| | Height h | Width b | Cutting plate left | Cutting plate right |
|---|---|---|---|---|
| ISO 5 | 16 | 16 | A 12 | B 12 |
| | 20 | 20 | A 16 | B 16 |
| | 25 | 25 | A 20 | B 20 |
| | 32 | 32 | A 25 | B 25 |
| ISO 6 | 10 | 10 | B 8 | A 8 |
| | 12 | 12 | B 10 | A 10 |
| | 16 | 16 | B 12 | A 12 |
| | 20 | 20 | B 16 | A 16 |
| | 25 | 25 | B 20 | A 20 |
| ISO 7 | 12 | 8 | D 3 | |
| | 16 | 10 | D 4 | |
| | 20 | 12 | D 5 | |
| | 26 | 16 | D 6 | |
| ISO 8+9 | | (Ø) | | min. hole ø |
| | 8 | 8 | A 5 | 14 |
| | 10 | 10 | A 6 | 18 |
| | 12 | 12 | A 8 | 21 |
| | 16 | 16 | A 10 | 27 |
| | 20 | 20 | A 12 | 34 |
| | 25 | 25 | A 16 | 43 |

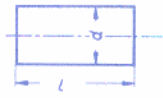
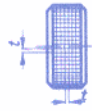
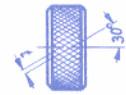
Form




1) Cutting plates are made of hard alloy DIN 4950 (Mar. 62)
2) B = shape; 8 = length of the cut
Example for the description of a turning tool
ISO 1 – R 1010 DIN 4971 – P 10 (R = right, 1010 = height – width
P 10 = cutting material)

## Standard values for pitches of straight, cross and diamond knurling ($l$)

DIN 82 (Jan. 40)

| Dimensions of workpiece in mm | | straight knurling for all materials | cross knurling for hard rubber | diamond knurling for steel, brass, al., fibre | |
|---|---|---|---|---|---|
|  | | |  |  | |
| Diameter $d$ | length $l$ | $t$ | $t$ | for brass, al., fibre $t =$ | for steel $t =$ |
| upto 8 | all lengths | 0.5 | 0.6 | 0.6 | 0.6 |
| from 8 – 16 | all lengths | 0.5 and 0.6 | 0.6 | 0.6 | 0.8 |
| from 16 – 32 | upto 6 | 0.5 and 0.6 | 0.6 | 0.6 | 0.8 |
| | above 6 | 0.8 | 0.8 | 0.8 | 1 |
| from 32 – 63 | upto 6 | 0.6 | 0.6 | 0.6 | 0.8 |
| | from 6 - 16 | 0.8 | 0.8 | 0.8 | 1 |
| | above 16 | 1 | 1 | 1 | 1.2 |
| from 63 – 100 | upto 6 | 0.8 | 0.8 | 0.8 | 0.8 |
| | from 6 - 16 | | | | 1 |
| | from 16 - 32 | 1 | 1 | 1 | 1.2 |
| | above 32 | 1.2 | 1.2 | 1.2 | 1.6 |

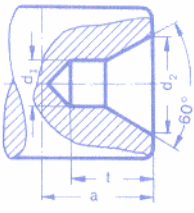
## Lubricants for thread cutting

| Material | Lubricant |
|---|---|
| Structural steel | Drilling oil emulsion |
| Cast steel | Drilling oil emulsion, rape oil |
| Tool steel | Rape oil |
| Alloy steel | Terpentine, petrol |
| Grey cast iron | Rape oil, petrol, dry |
| Malleable cast iron | Drilling oil emulsion, rape oil |
| Brass, bronze, copper | Rape oil, dry |
| Aluminium | Drilling oil emulsion, petrol, dry |
| Duraluminium | Rape oil |
| Silumin | Drilling oil emulsion, rape oil, dry |
| Electron metal, magnesium | Dry |

## Centre holes 60°

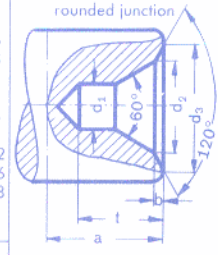
DIN 332 (Sept. 60)

Form A without counter sinking, rounded junction




| $d_1$ | Form A $a^{1)}$ | Form A $d_2$ | Form A $t^{2)}$ | Form B $a^{1)}$ | Form B $b$ | Form B $d_2$ | Form B $d_3$ | Form B $t^{2)}$ |
|---|---|---|---|---|---|---|---|---|
| (0.5) | 2 | 1.6 | 1.4 | – | – | – | – | – |
| (0.8) | 2.5 | 2 | 1.8 | – | – | – | – | – |
| 1 | 3 | 2.5 | 2.2 | 3.5 | 0.4 | 2.5 | 4 | 2.6 |
| (1.25) | 4 | 3.15 | 2.8 | 4.5 | 0.5 | 3.15 | 4.75 | 3.3 |
| 1.6 | 5 | 4 | 3.5 | 5.5 | 0.5 | 4 | 5.6 | 4 |
| (2) | 6 | 5 | 4.5 | 6.6 | 0.6 | 5 | 7.1 | 5.1 |
| 2.5 | 7 | 6.3 | 5.5 | 8.3 | 0.8 | 6.3 | 9 | 6.3 |
| (3.15) | 9 | 8 | 7 | 10 | 0.9 | 8 | 11.2 | 7.9 |
| 4 | 11 | 10 | 9 | 12.7 | 1.2 | 10 | 14 | 10.2 |
| (5) | 14 | 12.5 | 11 | 15.6 | 1.6 | 12.5 | 18 | 12.6 |
| 6.3 | 18 | 16 | 14 | 20 | 1.8 | 16 | 22.4 | 15.8 |
| (8) | 22 | 20 | 18 | – | – | – | – | – |
| 10 | 28 | 25 | 22 | – | – | – | – | – |

Form B with counter sinking, rounded junction




Description
Form A with $d_1 = 4$ mm
Centre hole A 4 DIN 332

As far as possible avoid sizes which have been bracketed

$^{1)}$ a is cut-off limit $^{2)}$ t is minimum limit

# Taper turning

## Setting the top slide

### Set to degrees

Top side is adjusted at the set angle $\frac{\alpha}{2}$ (half of the top angle) and is computed according to

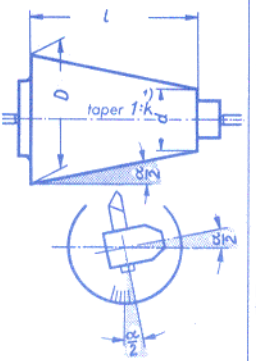
$$\tan\frac{\alpha}{2}=\frac{D-d}{2}:l=\frac{D-d}{2\cdot l}\cdot\frac{1}{2\cdot k}$$

From the calculated value, the tangent of $\frac{\alpha}{2}$ can be found from the table at page 66.

For further evaluation:

$$\frac{\alpha}{2}=\frac{D-d}{l}\cdot 28.6 \text{ or } \frac{D-d}{l}\cdot\frac{200}{7}$$

(exactly upto 6 deg. useful upto 12 deg.)

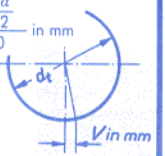



### Set to millimetres

If the setting angle $\frac{\alpha}{2}$ is known, the setting of the slide can be thus computed

$$V=\frac{\text{circumf. of swivel}\cdot\text{setting angle}}{360}$$

$$V=\frac{\pi\cdot d_1\cdot\frac{\alpha}{2}}{360}\text{ in mm}$$




If the setting angle is not known then

$$V=\frac{\text{Diameter of swivel}\cdot(D-d)}{4\cdot\text{taper length}}$$

$$V=\frac{d_1\cdot(D-d)}{4\cdot l}\text{ approximately}$$

**Solution:**

$$\tan\frac{\alpha}{2}=\frac{D-d}{2\cdot l}=\frac{83-73}{2\cdot 48}$$

$$=\frac{5}{48}=0.1042$$

$\frac{\alpha}{2}$ = according to tangent table 5° 57'

**Example:**

$D$ = 83 mm
$d$ = 73 mm
$l$ = 48 mm
$d_1$ = 180 mm

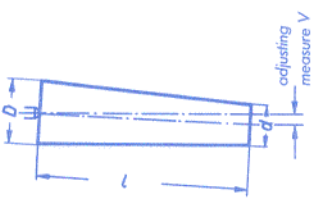
**Solution:**

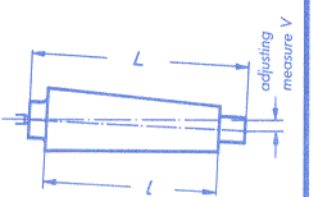
$$V=\frac{d_1\cdot(D-d)}{4\cdot l}=\frac{180\cdot(83-73)}{4\cdot 48}$$

$$=\frac{75}{8}=9.4\text{ mm}$$

## Adjusting the tail stock

The tail stock is shifted laterally till the surface line of the taper runs parallel to the spindle axis




Taper length = length of workpiece

$$V=\frac{D-d}{2}$$

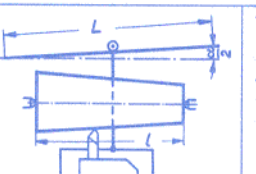
Applicable only for slender tapers

Taper length < length of the workpiece

$$V=\frac{D-d}{2\cdot l}\cdot L$$

## Taper turning using guide scale

For slender tapers upto a setting angle of 10 deg. and a turning length of about 500 mm

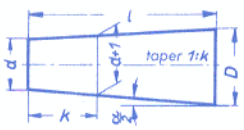



The guide scale is adjusted to half of the taper angle $\frac{\alpha}{2}$

The angle is computed as in setting of the top slide according to the tangent formula or according to $V\,(\text{mm})=\frac{D-d}{2}\cdot\frac{L}{l}$

## Tapers

DIN 254 (Jul. 62)

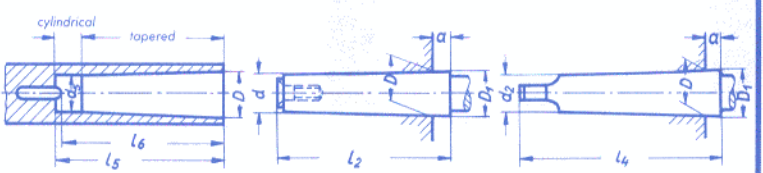



Tapers 1 : $k$ means:
that the diameter of the cone has narrowed by 1 mm for the length
$1 : k = (D - d) : l$

| Taper 1 : $k$ | Taper angle $\alpha$ | Setting angle for machine $\frac{\alpha}{2}$ | Examples for their application (M) = machine building industrie (W) = tool manufacturing industry |
|---|---|---|---|
| 1 : 0.289 | 120° | 60° | (M) Protective sinking for centre boring |
| 1 : 0.500 | 90° | 45° | (M) Valve taper, shoulders on piston rod, counter sunk screws |
| 1 : 0.866 | 60° | 30° | (M) Taper seals for light tube connections; V-grooves; centre boring; (W) central punching point on the top |
| 1 : 1.50 | 36° 52' | 18° 26' | (M) Taper seals for heavy pipe connections |
| 1 : 3.429 | 16° 35' 40" | 8° 18' | (W) Cutter or milling spindle nose (ISA-suggestions) |
| 1 : 4 | 14° 15' | 7° 7' 30" | (W) Machine tool manufacture, spindle head |
| 1 : 5 | 11° 25' 16" | 5° 42' 38" | (M) Pivot journal, friction clutches, machine elements easy to disengage, when subjected to loads lateral to axis and about the axis |
| 1 : 6 | 9° 31' 38" | 4° 45' 59" | (M) Taper seals for stop cocks, cross head pegs for locomotives |
| 1 : 10 | 5° 43' 30" | 2° 51' 45" | (M) Coupling bolts, adjustable bearing bushes, machine parts subjected to lateral ad torsional load and along the longitudinal axis |
| 1 : 15 | 3° 49' | 1° 54' 33" | Piston rods for locomotives, propeller hubs for ships |
| 1 : 20 | 2° 51' 52" | 1° 26' | (W) Metric taper shanks and shafts of tools and receiving lugs of machine tool spindles |
| (Morse taper see DIN 228) | | | |
| 1 : 30 | 1° 54' 34" | 57' 17" | (W) Boring of shell reamers and shell drills |
| 1 : 50 | 1° 8' 46" | 34' 23" | (M) Taper pins, tapered pipe threads |

## Tool tapers

DIN 254 (Jul. 62)

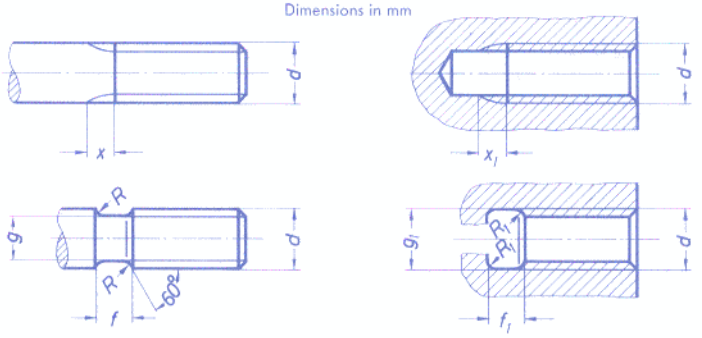



| Description | | Metric tapers | | Morse tapers | | | | | | | Metric tapers |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 4 | 6 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 80 |
| Bush | $D$ | 4 | 6 | 9.045 | 12.065 | 17.780 | 23,825 | 31.267 | 44.399 | 63.348 | 80 |
| | $d_5$ | 3 | 4.6 | 6.7 | 9.7 | 14.9 | 20.2 | 26.5 | 38.2 | 54.8 | 71.5 |
| | $l_5$ | 25 | 34 | 52 | 56 | 67 | 84 | 107 | 135 | 188 | 202 |
| | $l_6$ | 21 | 29 | 49 | 52 | 62 | 78 | 98 | 125 | 177 | 186 |
| Taper | $D_1$ | 4.1 | 6.2 | 9.2 | 12.2 | 18 | 24.1 | 31.6 | 44.7 | 63.8 | 80.4 |
| | $d$ | 2,85 | 4,40 | 6,453 | 9,396 | 14.583 | 19.784 | 25.933 | 37.574 | 53.905 | 70.2 |
| | $l_2$ | 25 | 35 | 53 | 57 | 69 | 86 | 109 | 136 | 190 | 204 |
| | $d_2$ | – | – | 6.115 | 8.972 | 14.059 | 19.132 | 25.154 | 36.547 | 52.419 | 69 |
| | $l_4$ | – | – | 59.5 | 65.5 | 78.5 | 98 | 123 | 155.5 | 217.5 | 228 |
| | $a$ | 2 | 3 | 3 | 3.5 | 5 | 5 | 6.5 | 6.5 | 8 | 8 |
| Tapers | | 1 : 20 | | 1 : 19.212 | 1 : 20.048 | 1 : 20.020 | 1 : 19.922 | 1 : 19.254 | 1 : 19.002 | 1 : 19.180 | 1 : 20 |
| Setting angle $\frac{\alpha}{2}$ | | 1° 25' 56" | | 1° 29' 27" | 1° 25' 43" | 1° 25' 50" | 1° 26' 16" | 1° 29' 15" | 1° 30' 26" | 1° 29' 36" | 1° 25' 56" |

## Screw thread runout  Screw thread undercut

DIN 76 (Juni 67)

Dimensions in mm




### For metric threads

| Thread Ø | Max. limit of runout | | Undercut | | | | | | Thread Ø | Max. limit of runout | | Undercut | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $d$ | $x$ | $x_1$ | $f$ | $g$ | $R$ | $f_1$ | $g_1$ | $R_1$ | $d$ | $x$ | $x_1$ | $f$ | $g$ | $R$ | $f_1$ | $g_1$ | $R_1$ |
| 2 | 1 | 0.8 | 1.2 | 1.3 | 0.2 | – | – | – | 20 | 6 | 5 | 7.5 | 16.4 | 1.2 | 10 | 20.5 | 1.6 |
| 2.3 | 1 | 0.8 | 1.2 | 1.6 | 0.2 | – | – | – | 22 | 6 | 5 | 7.5 | 18.4 | 1.2 | 10 | 22.5 | 1.6 |
| 2.5 | 1 | 0.9 | 1.4 | 1.8 | 0.2 | – | – | – | 24 | 7 | 6 | 9 | 19.6 | 1.6 | 12 | 24.5 | 2 |
| 2.6 | 1 | 0.9 | 1.4 | 1.9 | 0.2 | – | – | – | 27 | 7 | 6 | 9 | 22.6 | 1.6 | 12 | 27.5 | 2 |
| 3 | 1.2 | 1 | 1.5 | 2.2 | 0.3 | 2 | 3.3 | 0.5 | 30 | 8 | 7 | 10.5 | 25 | 1.6 | 14 | 30.5 | 2 |
| 3.5 | 1.6 | 1.2 | 1.8 | 2.5 | 0.3 | 2.4 | 3.8 | 0.5 | 33 | 8 | 7 | 10.5 | 28 | 1.6 | 14 | 33.5 | 2 |
| 4 | 1.6 | 1.4 | 2.1 | 2.9 | 0.4 | 2.8 | 4.3 | 0.6 | 36 | 10 | 8 | 12 | 30.3 | 2 | 16 | 36.5 | 2 |
| 5 | 2 | 1.6 | 2.4 | 3.7 | 0.4 | 3.2 | 5.3 | 0.6 | 39 | 10 | 8 | 12 | 33.3 | 2 | 16 | 39.5 | 2 |
| 6 | 2.5 | 2 | 3 | 4.4 | 0.5 | 4 | 6.5 | 0.8 | 42 | 11 | 9 | 13.5 | 35.6 | 2 | 18 | 42.5 | 2.5 |
| 7 | 2.5 | 2 | 3 | 5.4 | 0.5 | 4 | 7.5 | 0.8 | 45 | 11 | 9 | 13.5 | 38.6 | 2 | 18 | 45.5 | 2.5 |
| 8 | 3 | 2.5 | 3.8 | 6 | 0.6 | 5 | 8.5 | 1 | 48 | 12 | 10 | 15 | 41 | 2.5 | 20 | 48.5 | 2.5 |
| 10 | 3.5 | 3 | 4.5 | 7.7 | 0.8 | 6 | 10.5 | 1 | 52 | 12 | 10 | 15 | 45 | 2.5 | 20 | 52.5 | 2.5 |
| 12 | 4 | 3.5 | 5.3 | 9.4 | 1 | 7 | 12.5 | 1 | 56 | 13 | 11 | 16.5 | 48.3 | 3 | 22 | 56.5 | 3 |
| 14 | 5 | 4 | 6 | 11 | 1 | 8 | 14.5 | 1.2 | 60 | 13 | 11 | 16.5 | 52.3 | 3 | 22 | 60.5 | 3 |
| 16 | 5 | 4 | 6 | 13 | 1 | 8 | 16.5 | 1.2 | 64 | 15 | 12 | 18 | 55.7 | 3 | 24 | 64.5 | 3 |
| 18 | 6 | 5 | 7.5 | 14.4 | 1.2 | 10 | 18.5 | 1.6 | 68 | 15 | 12 | 18 | 59.7 | 3 | 24 | 68.5 | 3 |

## Radius of curvature R

DIN 250 (Jul. 72)

For heads, relief grooves and roundings of shafts, bores, plates and cast parts

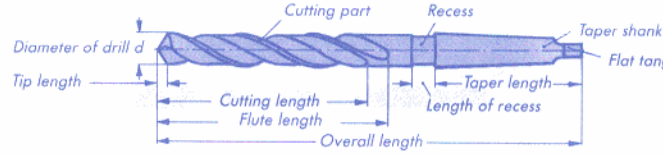
| Series 1 | Series 2 | Series 1 | Series 2 | Series 1 | Series 2 |
|---|---|---|---|---|---|
| 0.6 | 0.6 | | 8 | 40 | 40 |
| | 0.8 | 10 | 10 | | 45 |
| 1 | 1 | | 12 | 50 | 50 |
| | 1.2 | 16 | 16 | | 56 |
| 1.6 | 1.6 | | 18 | 63 | 63 |
| | 2 | 20 | 20 | | 70 |
| 2.5 | 2.5 | | 22 | 80 | 80 |
| | 3 | 25 | 25 | | 90 |
| 4 | 4 | | 28 | 100 | 100 |
| | 5 | 32 | 32 | | 110 |
| 6 | 6 | | 36 | 125 | 125 |

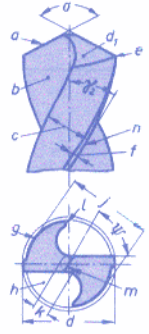
Series 1 is given priority over series 2

# Drilling

DIN 1412 (Dec. 66)

## Twist drill with taper shank



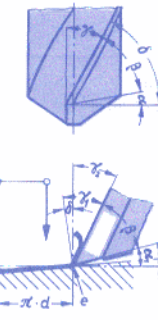




### Cutting part

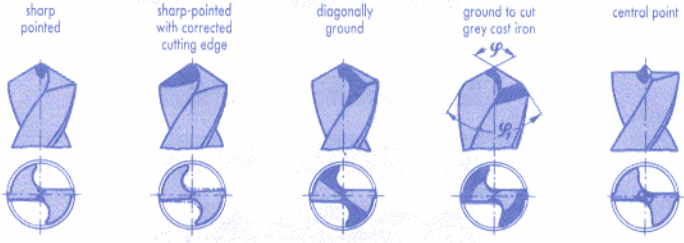
| | |
|---|---|
| $a$ | main cutting edge |
| $b$ | true rake |
| $c$ | web width |
| $d_1$ | major rake |
| $e$ | corner of cutting edge |
| $f$ | land width |
| $g$ | minor flank |
| $h$ | flute of drill |
| $j$ | flank diameter |
| $k$ | center thickness |
| $l$ | minor flank edge |
| $m$ | chisel edge |
| $n$ | minor cutting edge |
| $\sigma$ | point angle (Sigma) |
| $\psi$ | chisel edge angle ∢ |

### Angles at cutting edge

| | |
|---|---|
| $\alpha_1$ | relief angle at cutting edge |
| $\alpha_2$ | effective relief angle |
| $\beta$ | lip angle |
| $\gamma_1$ | true rake angle at cutting edges |
| $\gamma_2$ | helix angle at cutting angles |
| $\delta$ | feed angle |
| $e$ | corner of cutting edge |
| $s$ | feed |
| $\frac{s}{2}$ | depth of cut |
| $\pi \cdot d$ | circumference of drill |




## Specially ground drill points



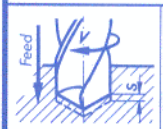

## Directions for using drill bits

DIN 1414 (Dec. 66)

| Material to be drilled | point angle $\varphi$ | helix angle $\gamma_2$ $d$ = 3.2...5 | frm 5..10 | ov. 10 |
|---|---|---|---|---|
| Steel and cast steel upto 690 N/mm² tensile strength<br>Grey cast iron<br>Malleable cast iron<br>Brass (hard)<br>German silver<br>Nickel | 118° | 22° | 25° | 30° |
| Brass (soft) | 118° | 12° | 13° | 13° |
| Steel and cast steel 690 to 1180 N/mm² tensile strength | 130° | 22° | 25° | 30° |
| Stainless steel<br>Copper, ab. 30 mm, Drill bit Ø, Al-alloy, forming short-broken chips | 140° | 22° | 25° | 30° |

| Material to be drilled | point angle $\varphi$ | helix angle $\gamma_2$ $d$ frm = 3.5...5 mm | ov. 5 mm |
|---|---|---|---|
| Copper upto 30 mm<br>Drill bit Ø<br>Al-alloy, forming long chips, Celluloid | 140° | 35° | 40° |
| Austenitic steel<br>Magnesium alloy | 140° | 12° | 13° |
| Moulded plastic with thickness $s \geq d$ | 80° | 35° | 40° |
| Moulded plastic $s \leq d$<br>Laminated plastic<br>Hard rubber, thin pressed materials<br>Marble, slate, coal | 80° | 12° | 13° |
| Zinc alloy<br>White metal | 118° | 35° | 40° |

# Cutting speed $v$ — Feed $s$ — Cooling




$v$ = Cutting speed = circumferential speed in m/min (depending upon the kind of material processed as well as the type of drill bit used. Also dependent on the feed and the depth of the hole to be drilled).

$s$ = Feed per turn in mm (depending on the material to be processed and the type and material of drill bit and its diameter).
Values shown in the table for standard length of 2000 mm and the depth of the hole $2 \cdot d$.

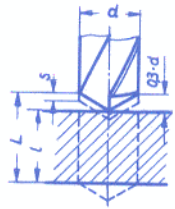
| Material | Cutting speed using tool steel drills | Feed $s$ (mm/rev.) / Cutting speed $v$ in m/min with low-alloyed high speed steel. / Diameter of drill | | | | | | | Cooling and lubricating agents |
|---|---|---|---|---|---|---|---|---|---|
| | | 5 Ø | 10 Ø | 15 Ø | 20 Ø | 25 Ø | 30 Ø | 35 Ø | |
| **Steel** | | 0.1 | 0.18 | 0.25 | 0.28 | 0.31 | 0.34 | 0.36 | Drilling oil emulsion or cutting and cooling oil |
| upto 390 N/mm² | ... 20 | 15 | 18 | 22 | 26 | 29 | 32 | 35 | |
| upto 590 N/mm² | ... 14 | 13 | 16 | 20 | 23 | 26 | 28 | 29 | |
| | | 0.07 | 0.13 | 0.16 | 0.19 | 0.21 | 0.23 | 0.25 | |
| upto 780 N/mm² | ... 10 | 12 | 14 | 16 | 18 | 21 | 23 | 24 | |
| upto 980 N/mm² | – | 8 | 10 | 13 | 15 | 17 | 18 | 19 | |
| above 980 N/mm² | – | 0.015 ... 0.17 mm/rev. | | | | | | | |
| | | 6 ... 12 m/min | | | | | | | |
| **Grey cast iron** | | 0.15 | 0.24 | 0.3 | 0.32 | 0.35 | 0.38 | 0.4 | Dry or plenty of drilling oil emulsion |
| upto 180 N/mm² | ... 14 | 24 | 28 | 32 | 34 | 37 | 39 | 40 | |
| upto 220 N/mm² | ... 10 | 16 | 18 | 21 | 24 | 26 | 27 | 28 | |
| | | 0.1 | 0.16 | 0.2 | 0.24 | 0.28 | 0.3 | 0.3 | |
| upto 290 N/mm² | ... 8 | 12 | 14 | 16 | 18 | 20 | 21 | 22 | |
| **Brass** | | 0.1 | 0.15 | 0.22 | 0.27 | 0.3 | 0.32 | 0.36 | Drilling oil emulsion or mineral oil |
| upto 390 N/mm² | ... 40 | 60 ... 70 m/min | | | | | | | |
| | | 0.07 | 0.12 | 0.18 | 0.24 | 0.25 | 0.28 | 0.32 | |
| upto 590 N/mm² | ... 25 | 40 ... 60 m/min | | | | | | | |
| **Bronze** | | 0.1 | 0.15 | 0.22 | 0.27 | 0.3 | 0.32 | 0.36 | |
| upto 290 N/mm² | ... 15 | 30 ... 40 m/min | | | | | | | |
| | | 0.05 | 0.08 | 0.12 | 0.18 | 0.2 | 0.22 | 0.26 | |
| upto 690 N/mm² | ... 12 | 25 ... 35 m/min | | | | | | | |
| **Aluminium** | | 0.05 | 0.12 | 0.2 | 0.3 | 0.35 | 0.4 | 0.46 | Drilling oil emulsion or cutting and cooling oil |
| pure | ... 50 | 80 ... 120 m/min | | | | | | | |
| **Aluminium** | | 0.12 | 0.2 | 0.3 | 0.4 | 0.46 | 0.5 | 0.6 | |
| alloys | ... 40 | 100 ... 150 m/min | | | | | | | |
| **Magnesium** | | 0.15 | 0.2 | 0.3 | 0.38 | 0.4 | 0.45 | 0.5 | Dry or special oils |
| alloys | ... 80 | 200 ... 250 m/min | | | | | | | |
| **Pressed material** | | 0.04 | 0.05 | 0.07 | 0.1 | 0.12 | 0.15 | 0.17 | Compressed air |
| not laminated | ... 15 | 35 ... 45 m/min | | | | | | | |

# Machining time calculations with drilling operations

The machinig time is the period of time in which a machine actually performs the drilling operation

**$n$ known**

$L$ = travel of tool
$L$ = depth of hole + point of drill
$L = l + 0.3 \cdot d$
$d$ = diameter of drill-bit in mm
$n$ = revolution per minute
$s$ = feed in mm/rev.
$s \cdot n$ = feed/minute = $s^1$




**$n$ not known**

$L = l + 0.3 \cdot d$
$d$ = diameter of drill-bit in mm
$s$ = feed in mm/rev.
$v$ = cutting speed m/min

$$v = \frac{\pi \cdot d \cdot n}{1000}$$

$$n = \frac{v \cdot 1000}{\pi \cdot d}$$

$$t_h = \frac{L}{s \cdot n} \text{ in min}$$

$$\text{Machining time} = \frac{\text{travel of tool}}{\text{feed/min}}$$

$$t_h = \frac{L \cdot \pi \cdot d}{s \cdot v \cdot 1000} \text{ in min}$$

**Example:**

$l$ = 35 mm $d$ = 30 mm
$s$ = 0,2 mm/rev. n = 300 r.p.m.
$L = l + 0.3 \cdot d = 35 + 9 = 44$ mm

$$t_h = \frac{L}{s \cdot n} = \frac{44}{0.2 \cdot 300} = \mathbf{0.73 \text{ min}}$$

**Example:**

$l$ = 35 mm $d$ = 30 mm
$s$ = 0.2 mm/rev. $v$ = 28 m/min
$L = l + 0.3 \cdot d = 35 + 9 = 44$ mm

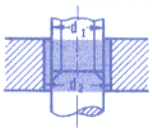
$$t_h = \frac{L \cdot \pi \cdot d}{s \cdot v \cdot 1000} = \frac{44 \cdot 3.14 \cdot 30}{0.2 \cdot 28000} = \mathbf{0.73 \text{ min}}$$

## Machining time in min per 10 mm tool travel

| r.p.m. $\frac{1}{\text{min}}$ | Feed $s$ in mm rev. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0.1 | 0.12 | 0.16 | 0.2 | 0.25 | 0.32 | 0.4 | 0.5 | 0.65 |
| | Machining time $t_h$ in min/10 mm | | | | | | | | |
| 11.2 | 8.93 | 7.44 | 5.85 | 4.46 | 3.57 | 2.79 | 2.23 | 1.78 | 1.38 |
| 14 | 7.15 | 5.95 | 4.46 | 3.57 | 2.85 | 2.23 | 1.78 | 1.43 | 1.09 |
| 18 | 5.56 | 4.36 | 3.47 | 2.77 | 2.22 | 1.73 | 1.39 | 1.11 | 0.85 |
| 22.4 | 4.47 | 3.71 | 2.79 | 2.23 | 1.78 | 1.39 | 1.11 | 0.89 | 0.68 |
| 28 | 3.57 | 2.97 | 2.23 | 1.78 | 1.42 | 1.11 | 0.88 | 0.71 | 0.55 |
| 35.5 | 2.82 | 2.34 | 1.76 | 1.40 | 1.12 | 0.86 | 0.70 | 0.56 | 0.43 |
| 45 | 2.22 | 1.85 | 1.39 | 1.11 | 0.88 | 0.69 | 0.55 | 0.44 | 0.34 |
| 56 | 1.79 | 1.31 | 1.12 | 0.89 | 0.71 | 0.55 | 0.44 | 0.36 | 0.27 |
| 71 | 1.41 | 1.17 | 0.88 | 0.70 | 0.53 | 0.44 | 0.35 | 0.28 | 0.21 |
| 90 | 1.11 | 0.92 | 0.69 | 0.55 | 0.44 | 0.34 | 0.28 | 0.22 | 0.17 |
| 112 | 0.89 | 0.74 | 0.58 | 0.44 | 0.36 | 0.28 | 0.22 | 0.18 | 0.14 |
| 140 | 0.71 | 0.59 | 0.44 | 0.36 | 0.28 | 0.22 | 0.18 | 0.14 | 0.109 |
| 180 | 0.55 | 0.43 | 0.35 | 0.28 | 0.22 | 0.17 | 0.14 | 0.111 | 0.085 |
| 224 | 0.45 | 0.37 | 0.28 | 0.22 | 0.18 | 0.13 | 0.111 | 0.089 | 0.068 |
| 280 | 0.36 | 0.29 | 0.22 | 0.18 | 0.14 | 0.111 | 0.088 | 0.071 | 0.055 |
| 355 | 0.28 | 0.23 | 0.17 | 0.14 | 0.112 | 0.086 | 0.070 | 0.056 | 0.043 |
| 450 | 0.22 | 0.18 | 0.14 | 0.111 | 0.088 | 0.069 | 0.055 | 0.044 | 0.034 |
| 560 | 0.18 | 0.13 | 0.112 | 0.089 | 0.071 | 0.055 | 0.044 | 0.036 | 0.027 |
| 710 | 0.14 | 0.117 | 0.088 | 0.070 | 0.053 | 0.044 | 0.035 | 0.028 | 0.021 |
| 900 | 0.111 | 0.092 | 0.069 | 0.055 | 0.044 | 0.034 | 0.028 | 0.022 | 0.017 |
| 1120 | 0.089 | 0.074 | 0.058 | 0.044 | 0.036 | 0.028 | 0.022 | 0.018 | 0.014 |
| 1400 | 0.071 | 0.059 | 0.044 | 0.036 | 0.028 | 0.022 | 0.018 | 0.014 | 0.011 |
| 1800 | 0.055 | 0.043 | 0.035 | 0.028 | 0.022 | 0.017 | 0.014 | 0.011 | 0.008 |
| 2240 | 0.045 | 0.037 | 0.028 | 0.022 | 0.018 | 0.013 | 0.011 | 0.009 | 0.007 |
| 2800 | 0.036 | 0.029 | 0.022 | 0.018 | 0.014 | 0.011 | 0.009 | 0.007 | 0.006 |

## Through holes

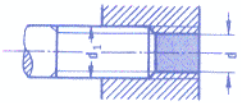
DIN 69 (Aug. 71)




## Drill-bit diameter for tapping drill holes

DIN 336 (Apr. 69)

The following applies for metric threads
diameter of hole = thread diameter minus pitch




| Screws | Through holes | | | For metric ISO-regulations for threads DIN 13 Pg. 1 & 34 | | | For metric ISO-fine threads as per DIN 13 Pg. 35 upto 40 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Thread diameter | fine | medium | coarse | Thread nominal diameter | Pitch | Drill-bit Ø | Thread nominal diameter | Pitch in mm | | | | | | | |
| | drill-bit Ø | | | | | | | 0.35 | 0.5 | 0.75 | 1 | 1.25 | 1.5 | 2 | 3 | 4 |
| | | | | | | | meter Ø | Ø Hole diameter Ø | | | | | | | | |
| $d_1$ | $d_2$ | | | $d_1$ | | $d$ | $d_1$ | $d$ | | | | | | | | |
| 1 | 1.1 | 1.2 | 1.3 | M 1 | 0.25 | 0.75 | 3 | 0.35 | | | 2.7 | | | | | |
| 1.2 | 1.3 | 1.4 | 1.5 | M 1.2 | 0.25 | 0.95 | 3.5 | | | | 3.2 | | | | | |
| 1.4 | 1.5 | 1.6 | 1.8 | M 1.4 | 0.3 | 1.1 | 4 | | 0.5 | | 3.5 | | | | | |
| 1.6 | 1.7 | 1.8 | 2 | | | | 4.5 | | | | 4 | | | | | |
| 1.7 | 1.8 | 1.9 | 2.2 | M 2 | 0.4 | 1.6 | 5 | | | | 4.5 | | | | | |
| | | | | | | | 5.5 | | | | 5 | | | | | |
| 2 | 2.2 | 2.4 | 2.6 | M 2.2 | 0.45 | 1.75 | | | | | | | | | | |
| 2.3 | 2.5 | 2.7 | 2.9 | M 2.5 | 0.45 | 2.05 | 6 | | | | 5.2 | | | | | |
| 2.5 | 2.7 | 2.9 | 3.1 | M 3 | 0.5 | 2.5 | 7 | | | | 6.2 | | | | | |
| 2.6 | 2.8 | 3 | 3.2 | M 3.5 | 0.6 | 2.9 | 8 | | | | 7.2 | 7 | | | | |
| | | | | | | | 9 | | | 0.75 | 8.2 | 8 | | | | |
| 3 | 3.2 | 3.4 | 3.6 | M 4 | 0.7 | 3.3 | 10 | | | | 9.2 | 9 | 8.8 | | | |
| 3.5 | 3.7 | 3.9 | 4.1 | M 5 | 0.8 | 4.2 | 11 | | | | 10.2 | 10 | | | | |
| 4 | 4.3 | 4.5 | 4.8 | M 6 | 1 | 5 | | | | | | | | | | |
| 5 | 5.3 | 5.5 | 5.8 | M 7 | 1 | 6 | 12 | | | | | 11 | 10.8 | 10.5 | | |
| 6 | 6.4 | 6.6 | 7 | M 8 | 1.25 | 6.8 | 14 | | | | | 13 | 12.8 | 12.5 | | |
| 7 | 7.4 | 7.6 | 8 | M 9 | 1.25 | 7.8 | 15 | | | | | 14 | | 13.5 | | |
| 8 | 8.4 | 9 | 10 | | | | 16 | | | | | 15 | | 14.5 | | |
| | | | | M 10 | 1.5 | 8.5 | 17 | | | | | 16 | | 15.5 | | |
| 10 | 10,5 | 11 | 12 | M 11 | 1.5 | 9.5 | 18 | | | | | 17 | | 16.5 | 16 | |
| 12 | 13 | 14 | 15 | M 12 | 1.75 | 10.2 | | | | | | | | | | |
| 14 | 15 | 16 | 17 | M 14 | 2 | 12 | 20 | | | | | 19 | | 18.5 | 18 | |
| 16 | 17 | 18 | 19 | M 16 | 2 | 14 | 22 | | | | | 21 | | 20.5 | 20 | |
| 18 | 19 | 20 | 21 | M 18 | 2.5 | 15.5 | 24 | | | | | 23 | | 22.5 | 22 | |
| | | | | | | | 25 | | | | | 24 | | 23.5 | 23 | |
| 20 | 21 | 22 | 24 | M 20 | 2.5 | 17.5 | 27 | | | | | 26 | | 25.5 | 25 | |
| 22 | 23 | 24 | 26 | M 22 | 2.5 | 19.5 | 28 | | | | | 27 | | 26.5 | 26 | |
| 24 | 25 | 26 | 28 | M 24 | 3 | 21 | | | | | | | | | | |
| 27 | 28 | 30 | 32 | M 27 | 3 | 24 | 30 | | | | | 29 | | 28.5 | 28 | 27 |
| | | | | | | | 32 | | | | | | | 30.5 | 30 | |
| 30 | 31 | 33 | 35 | M 30 | 3.5 | 26.5 | 33 | | | | | | | 31.5 | 31 | 30 |
| 33 | 34 | 36 | 38 | M 33 | 3.5 | 29.5 | 35 | | | | | | | 33.5 | | |
| 36 | 37 | 39 | 42 | M 36 | 4 | 32 | 36 | | | | | | | 34.5 | 34 | 33 |
| 39 | 40 | 42 | 45 | M 39 | 4 | 35 | 39 | | | | | | | 37.5 | 37 | 36 |
| | | | | | | | 40 | | | | | | | 38.5 | 38 | 37 |
| 42 | 43 | 45 | 48 | M 42 | 4.5 | 37.5 | 42 | | | | | | | 40.5 | 40 | 39 | 38 |
| 45 | 46 | 48 | 52 | M 45 | 4.5 | 40.5 | 45 | | | | | | | 43.5 | 43 | 42 | 41 |
| 48 | 50 | 52 | 56 | M 48 | 5 | 43 | 48 | | | | | | | 46.5 | 46 | 45 | 44 |
| 52 | 54 | 56 | 62 | M 52 | 5 | 47 | | | | | | | | | | |
| 56 | 58 | 62 | 66 | M 56 | 5.5 | 50.5 | 50 | | | | | | | 48.5 | 48 | 47 | |
| 60 | 62 | 66 | 70 | | | | 52 | | | | | | | 50.5 | 50 | 49 | 48 |
| 64 | 66 | 70 | 74 | | | | | | | | | | | | | | |

While thread cutting, the difference between the various types of material is so small that for the diameters of the drill-bits recommended in these standards it can be ignored.

# Countersinking

DIN 74
(Jul. 71, March 72)

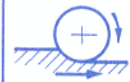
| Thread - Ø | | M1 | M1,6 | M2 | M3 | M4 | M5 | M6 | M8 | M10 | M12 | M16 | M20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Countersunk screws | | Form A *for DIN 963, 965, 964, 966, 7513, 7516* | | | | | | | | | | | |
| | $a$ | 90° | | | | | | | | | | | |
| | $d_1$ | 1.2 | 1.8 | 2.4 | 3.4 | 4.5 | 5.5 | 6.6 | 9 | 11 | 14 | 18 | 22 |
| | $d_2$ | 2.4 | 3.7 | 4.6 | 6.5 | 8.6 | 10.4 | 12.4 | 16.4 | 20.4 | 24.4 | 32.4 | 40.4 |
| | $t_1$ | 0.6 | 0.9 | 1.1 | 1.6 | 2.1 | 2.5 | 2.9 | 3.7 | 4.7 | 5.2 | 7.2 | 9.2 |
| | | Form B for DIN 7991 | | | | | | | | | | | |
| | $a$ | 90° | | | | | | | | | | | |
| | $d_1$ | – | – | – | 3.4 | 4.5 | 5.5 | 6.6 | 9 | 11 | 14 | 18 | 22 |
| Type: | $d_2$ | – | – | – | 6.6 | 9 | 11 | 13 | 17.2 | 21.5 | 26 | 32 | 35 |
| medium (m) | $t_1$ | – | – | – | 1.6 | 2.3 | 2.8 | 3.2 | 4.1 | 5.3 | 6 | 7 | 8 |
| | | Form D for wood screws DIN 97, 7997, 95, 7995 | | | | | | | | | | | |
| | $a$ | 90° | | | | | | | | | | | |
| | $d_1$ | – | – | 2.2 | 3.2 | 4.3 | 5.3 | 6.4 | 8.4 | 10.5 | – | – | – |
| | $d_2$ | – | – | 4.2 | 6.2 | 8.3 | 10.3 | 12.4 | 16.4 | 20.5 | – | – | – |
| | $t_1$ | – | – | 1 | 1.5 | 2 | 2.5 | 3 | 4 | 5 | – | – | – |
| | | Form E for countersunk screws DIN 7669 | | | | | | | | | | | |
| | $a$ | 75° | | | | | | | | | | | 60° |
| | $d_1$ | – | – | – | – | – | – | – | – | 10.5 | 13 | 17 | 21 |
| | $d_2$ | – | – | – | – | – | – | – | – | 19 | 24 | 31 | 34 |
| | $t_1$ | – | – | – | – | – | – | – | – | 5.5 | 7 | 9 | 11.5 |
| Cylindrical screws | | Form H for DIN 84, 7513, 7984<br>Form J for DIN 6912<br>Form K for DIN 912 | | | | | | | | | | | |
| | $d_1$ | 1.2 | 1.8 | 2.4 | 3.4 | 4.5 | 5.5 | 6.6 | 9 | 11 | 14 | 18 | 22 |
| | $d_2$ | 2.2 | 3.3 | 4.3 | 6 | 8 | 10 | 11 | 15 | 18 | 20 | 26 | 33 |
| | $d_3$ | – | – | – | – | – | – | – | – | – | 16 | 20 | 24 |
| Form H | $t$ | 0.8 | 1.2 | 1.6 | 2.4 | 3.2 | 4 | 4.7 | 6 | 7 | 8 | 10.5 | 12.5 |
| Form J | $t$ | – | – | – | – | 3.4 | 4.2 | 4.8 | 6 | 7.5 | 8.5 | 11.5 | 13.5 |
| Form K | $t$ | – | 1.8 | 2.3 | 3.4 | 4.6 | 5.7 | 6.8 | 9 | 11 | 13 | 17.5 | 21.5 |
| Type: medium (m) | | Form H1, H2, H3 for DIN 84, 7513, 7984<br>Form J1, J2, J3 for DIN 6912 (with rings or washers)<br>Form K1, K2, K3 for DIN 912 | | | | | | | | | | | |
| Form: | $d_1$ | – | – | 2.4 | 3.4 | 4.5 | 5.5 | 6.6 | 9 | 11 | 14 | 18 | 22 |
| H1, J1, K1 | $d_2$ | – | – | 5.5 | 7 | 9 | 11 | 13 | 18 | 20 | 24 | 30 | 36 |
| H2, J2, K2 | $d_2$ | – | – | 6 | 9 | 10 | 13 | 13 | 20 | 24 | 26 | 33 | 40 |
| H3, J3, K3 | $d_2$ | – | – | – | 6 | 8 | 10 | 11 | 15 | 18 | 20 | 26 | 33 |
| H1, H2, H3 | $t$ | – | – | 2.2 | 3.3 | 4.5 | 5.5 | 6.5 | 8 | 9.5 | 11 | 14 | 16.5 |
| J1, J2, J3 | $t$ | – | – | – | – | 4.5 | 5.5 | 6.5 | 8 | 9.5 | 11 | 15 | 17.5 |
| K1, K2, K3 | $t$ | – | – | – | 4.3 | 5.5 | 7 | 8.5 | 11 | 13.5 | 16 | 21 | 25.5 |
| Hexagonal screws, nuts | | Form R for DIN 931, 934 | | | | | | | | | | | |
| | $d_1$ | – | – | 2.4 | 3.4 | 4.5 | 5.5 | 6.6 | 9 | 11 | 14 | 18 | 22 |
| Hexagonal nut DIN 934 | $d_2$ | – | – | 6 | 9 | 10 | 11 | 13 | 18 | 22 | 26 | 33 | 40 |
| | $d_3$ | – | – | – | – | – | – | – | – | – | 16 | 20 | 24 |
| | | used for manufacture of circular surface | | | | | | | | | | | |
| h = 0.8 d | | Form SA, SB for DIN 931 (1.2 with rings or washers)<br>Form TA, TB for DIN 934 | | | | | | | | | | | |
| Form: | $d_1$ | – | – | – | 3.4 | 4.5 | 5.5 | 6.6 | 9 | 11 | 14 | 18 | 22 |
| SA, TA | $d_2$ | – | – | – | 11 | 13 | 15 | 18 | 24 | 28 | 33 | 40 | 46 |
| SB, TB | $d_2$ | – | – | – | 11 | 15 | 18 | 20 | 26 | 33 | 36 | 46 | 53 |
| SA, SB | $t$ | – | – | – | 2.4 | 3.4 | 4.2 | 4.8 | 6.5 | 8 | 9 | 11.5 | 14.5 |
| TA, TB | $t$ | – | – | – | 2.8 | 3.8 | 4.7 | 5.8 | 7.5 | 9 | 11 | 14.5 | 17.5 |

# Milling

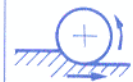
## Standard data for number of teeth and lip angles of high speed steel cutters

$\alpha$ = clearance angle
$\gamma$ = radial rake angle

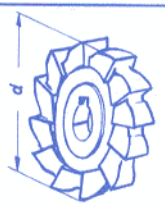
$\lambda$ = Rake of cutting edge toward axis



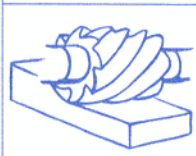
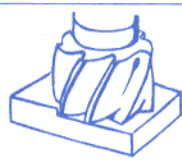
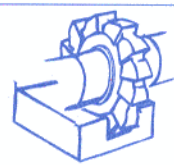
Conventional milling (up-milling)

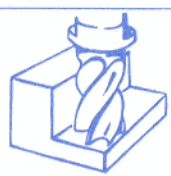
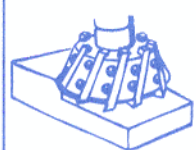
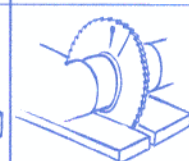


Climb milling (down milling)

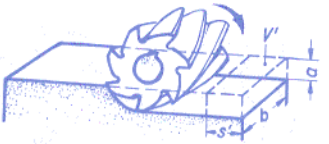
| Types of cutter | Normal steels upto 740 N/mm² strength | | | | | Tough materials upto 980 N/mm² strength | | | | | Light metals | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ø | Number of teeth | lip angle ∢ | | | Ø | Number of teeth | lip angle ∢ | | | Ø | Number of teeth | lip angle ∢ | | |
| | d | z | α | γ | λ | d | z | α | γ | λ | d | z | α | γ | λ |
| Cylindrical milling cutter | 40 | 6 | up-milling | | | 40 | 10 | up-milling | | | 40 | 4 | up-milling | | |
| | 50 | 6 | 7° | 10° | 38° | 50 | 10 | 4° | 5° | 35° | 50 | 4 | 8° | 25° | 45° |
| | 60 | 6 | | | | 60 | 10 | | | | 60 | 4 | | | |
| | 75 | 6 | | | | 75 | 12 | | | | 75 | 5 | | | |
| | 90 | 8 | down-milling | | | 90 | 14 | down-milling | | | 90 | 5 | down-milling | | |
| | 110 | 8 | 12° | 16° | 35° | 110 | 16 | 8° | 12° | 30° | 110 | 6 | 14° | 30° | 45° |
| | 130 | 10 | | | | 130 | 16 | | | | 130 | 6 | | | |
| | 150 | 10 | | | | 150 | 18 | | | | 150 | 8 | | | |
| Face milling cutter | 40 | 8 | up-milling | | | 40 | 12 | up-milling | | | 40 | 4 | up-milling | | |
| | 50 | 10 | 7° | 10° | 20° | 50 | 14 | 4° | 5° | 20° | 50 | 5 | 8° | 25° | 35° |
| | 60 | 10 | | | | 60 | 14 | | | | 60 | 6 | | | |
| | 75 | 10 | | | | 75 | 16 | | | | 75 | 6 | | | |
| | 90 | 12 | | | | 90 | 18 | | | | 90 | 6 | | | |
| | 110 | 12 | | | | 110 | 20 | | | | 110 | 7 | | | |
| | 130 | 14 | | | | 130 | 22 | | | | 130 | 8 | | | |
| | 150 | 16 | | | | 150 | 24 | | | | 150 | 10 | | | |
|  Side and face milling cutter | 50 | 10 | up-milling | | | 50 | 16 | up-milling | | | 50 | 4 | up-milling | | |
| | 60 | 10 | α | γ | λ | 60 | 16 | α | γ | λ | 60 | 6 | α | γ | λ |
| | 75 | 12 | 7° | 12° | 15° | 75 | 18 | 5° | 6° | 10° | 75 | 6 | 8° | 25° | 30° |
| | 90 | 12 | | | | 90 | 20 | | | | 90 | 8 | | | |
| | 110 | 14 | | | | 110 | 22 | | | | 110 | 8 | | | |
| | 130 | 16 | down-milling | | | 130 | 24 | down-milling | | | 130 | 10 | down-milling | | |
| | 150 | 18 | α | γ | λ | 150 | 26 | α | γ | λ | 150 | 10 | α | γ | λ |
| | 175 | 18 | 12° | 18° | 15° | 175 | 28 | 8° | 14° | 12° | 175 | 12 | 14° | 30° | 30° |
| | 200 | 20 | | | | 200 | 30 | | | | 200 | 12 | | | |
| End milling cutter | 10 | 4 | up-milling | | | 10 | 6 | up-milling | | | 10 | 3 | up-milling | | |
| | 12 | 4 | 7° | 8° | 15° | 12 | 6 | 4° | 6° | 15° | 12 | 3 | 8° | 20° | 25° |
| | 14 | 5 | | | | 14 | 6 | | | | 14 | 3 | | | |
| | 16 | 5 | | | | 16 | 8 | | | | 16 | 3 | | | |
| | 20 | 6 | | | | 20 | 8 | | | | 20 | 4 | | | |
| | 24 | 6 | | | | 24 | 8 | | | | 24 | 4 | | | |
| | 30 | 6 | | | | 30 | 10 | | | | 30 | 4 | | | |
| | 36 | 6 | | | | 36 | 10 | | | | 36 | 5 | | | |
| | 40 | 6 | | | | 40 | 10 | | | | 40 | 5 | | | |

## Standard data for cutting speed and feed

| | Cylindrical milling | | | | Face milling | | | | Side and face milling | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| |  | | | |  | | | |  | | | |
| Milling width $b$ | $b$ = 100 mm | | | | $b$ = 70 mm | | | | $b$ = 20 mm | | | |
| | Roughing ▽ | | Finishing ▽▽ | | Roughing ▽ | | Finishing ▽▽ | | Roughing ▽ | | Finishing ▽▽ | |
| Depth of cut $a$ | $a$ = 5 mm | | $a$ = 0,5 mm | | $a$ = 5 mm | | $a$ = 0,5 mm | | $a$ = 10 mm | | | |
| | Cutting speed $v$ m/min | Feed $s'$ mm/min | Cutting speed $v$ m/min | Feed $s'$ mm/min | Cutting speed $v$ m/min | Feed $s'$ mm/min | Cutting speed $v$ m/min | Feed $s'$ mm/min | Cutting speed $v$ m/min | Feed $s'$ mm/min | Cutting speed $v$ m/min | Feed $s'$ mm/min |
| Plain steel upto 640 N/mm² | 17 | 100 | 22 | 60 | 17 | 100 | 22 | 70 | 18 | 100 | 22 | 40 |
| Alloy steel, annealed upto 740 N/mm² | 14 | 80 | 18 | 50 | 14 | 90 | 18 | 55 | 14 | 80 | 18 | 30 |
| Alloy steel, heat-treated upto 980 N/mm² | 10 | 50 | 14 | 36 | 10 | 55 | 14 | 42 | 12 | 50 | 14 | 25 |
| Grey cast iron upto 180 HB | 12 | 120 | 18 | 60 | 12 | 140 | 18 | 70 | 14 | 120 | 18 | 40 |
| Brass | 35 | 70 | 35 | 50 | 36 | 190 | 55 | 150 | 36 | 150 | 55 | 75 |
| Light metal | 200 | 200 | 250 | 100 | 200 | 250 | 250 | 110 | 200 | 200 | 250 | 100 |

| | End milling cutter | | | | Inserted tooth face milling cutter | | | | Circular saw | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| |  | | | |  | | | |  | | | |
| Milling width $b$ | $b$ = 25 mm | | | | $b$ = 180 mm | | | | $b$ = 2.5 mm | | | |
| | Roughing ▽ | | Finishing ▽▽ | | Roughing ▽ | | Finishing ▽▽ | | Roughing ▽ | | | |
| Depth of cut $a$ | $a$ = 5 mm | | $a$ = 0,5 mm | | $a$ = 5 mm | | $a$ = 0,5 mm | | $a$ = 10 mm | | | |
| | Cutting speed $v$ m/min | Feed $s'$ mm/min | Cutting speed $v$ m/min | Feed $s'$ mm/min | Cutting speed $v$ m/min | Feed $s'$ mm/min | Cutting speed $v$ m/min | Feed $s'$ mm/min | Cutting speed $v$ m/min | Feed $s'$ mm/min | | |
| Plain steel upto 640 N/mm² | 17 | 50 | 22 | 120 | 20 | 65 | 30 | 50 | 45 | 50 | | |
| Alloy steel, annealed upto 740 N/mm² | 15 | 40 | 19 | 100 | 16 | 36 | 23 | 40 | 35 | 40 | | |
| Alloy steel, heat-treated upto 980 N/mm² | 13 | 20 | 17 | 65 | 14 | 20 | 18 | 30 | 25 | 30 | | |
| Grey cast iron upto 180 HB | 15 | 60 | 19 | 120 | 16 | 100 | 24 | 90 | 35 | 50 | | |
| Brass | 35 | 80 | 55 | 120 | 50 | 200 | 60 | 120 | 350 | 200 | | |
| Light metal | 160 | 90 | 180 | 120 | 250 | 250 | 300 | 90 | 320 | 180 | | |

## Permissible rate of chip removal

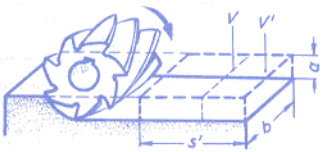



The permissible rate of chip removal $V'$ in $cm^3$ per kW min. of machine driving power

| Type of cutter | Plain steel 340...590 $N/mm^2$ strength | Alloy steel (annealed) 590...780 $N/mm^2$ | Alloy steel (hardened) upto 980 $N/mm^2$ | Grey cast iron (medium hard) | Brass & red brass | Light alloys |
|---|---|---|---|---|---|---|
| Slab milling | 12 | 10 | 8 | 22 | 30 | 60 |
| Face milling | 15 | 12 | 10 | 28 | 40 | 75 |

$cm^3$ per kW min

## Calculating the rate of feed




The maximum chip removal rate $V$ can be obtained from the permissible chip removal rate $V'$ and machine driving power $P$

Maximum rate of chip removal = permissible rate of chip removal · machine driving power

$$V = V' \cdot P \quad \text{in } cm^3/min$$

The rate of chip removal can be found by multiplying the depth of the cut $a$, milling width $b$, and the rate of feed $s'$. It would be:

$$\text{Rate of chip removal} = \frac{\text{depth of cut} \cdot \text{milling width} \cdot \text{rate of feed}}{1000}$$

$$V = \frac{a \cdot b \cdot s'}{1000}$$

The rate of feed is thus determined in $s'$ as

$$s' = \frac{V \cdot 1000}{a \cdot b} \quad \text{in mm/min}$$

**Example:** A workpiece made of St 50 is to be milled. The power of the milling machine is 2.5 kW. Depth of the cut $a = 5$ mm, milling width $b = 100$ mm. Calculate the rate of feed $s'$.

Maximum rate of metal removal $V = V' \cdot P$ ($V' = 12$ $cm^3$/kW min according to the table)

$V = 12 \cdot 2.5$

$V = 30$ $cm^3$/min

$$\text{Rate of feed } s' = \frac{V \cdot 1000}{a \cdot b} = \frac{30 \cdot 1000}{5 \times 100} = 60 \text{ mm/min}$$

## Rate of feed s' based on the permissible rate of chip removal V'

| Permissible rate of chip removal V' cm³/kW min | Depth of cut a mm | s' with a machine driving power P = 1 kW * Width b of cut in mm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 40 | 50 | 60 | 80 | 100 | 120 | 140 | 160 | 180 |
| 8 | 3 | 66 | 53 | 44 | 33 | 26 | 22 | 19 | 16 | 15 |
| | 5 | 40 | 32 | 27 | 20 | 16 | 13 | 11 | 10 | 9 |
| | 8 | 25 | 20 | 16 | 12 | 10 | 8 | 7 | 6 | 5.5 |
| 10 | 3 | 83 | 66 | 55 | 41 | 33 | 27 | 23 | 20 | 18 |
| | 5 | 50 | 40 | 33 | 25 | 20 | 16 | 14 | 12 | 11 |
| | 8 | 31 | 25 | 21 | 15 | 12.5 | 10 | 9 | 8 | 7 |
| 12 | 3 | 100 | 80 | 67 | 50 | 40 | 33 | 29 | 25 | 22 |
| | 5 | 60 | 48 | 40 | 30 | 24 | 20 | 17 | 15 | 13 |
| | 8 | 37 | 30 | 25 | 19 | 15 | 12 | 10 | 9 | 8 |
| 15 | 3 | 125 | 100 | 84 | 62 | 50 | 42 | 36 | 31 | 28 |
| | 5 | 75 | 60 | 50 | 37 | 30 | 25 | 21 | 19 | 16 |
| | 8 | 47 | 37 | 31 | 21 | 19 | 15 | 13 | 11 | 10 |
| 22 | 3 | 184 | 146 | 121 | 92 | 73 | 61 | 52 | 46 | 41 |
| | 5 | 110 | 88 | 73 | 55 | 44 | 37 | 31 | 27 | 24 |
| | 8 | 69 | 55 | 46 | 34 | 27 | 23 | 19 | 17 | 15 |
| 28 | 3 | 230 | 185 | 155 | 116 | 94 | 78 | 67 | 58 | 52 |
| | 5 | 140 | 110 | 93 | 70 | 56 | 47 | 40 | 35 | 31 |
| | 8 | 87 | 70 | 58 | 44 | 35 | 29 | 25 | 22 | 19 |
| 60 | 3 | 500 | 400 | 335 | 250 | 200 | 165 | 142 | 125 | 110 |
| | 5 | 300 | 240 | 200 | 150 | 120 | 100 | 86 | 75 | 67 |
| | 8 | 185 | 150 | 125 | 94 | 75 | 62 | 53 | 47 | 42 |
| 75 | 3 | 625 | 500 | 415 | 310 | 250 | 205 | 178 | 156 | 140 |
| | 5 | 375 | 300 | 250 | 185 | 150 | 125 | 105 | 94 | 83 |
| | 8 | 235 | 185 | 155 | 115 | 94 | 78 | 67 | 58 | 52 |

* If the driving power $P = 2.5$ kW or 5 kW, the values shown in the table are to be multiplied with 2.5 or 5 respectively.

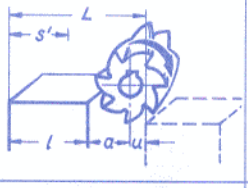
## Calculating the machining time

$$\text{Machining time} = \frac{\text{travel of milling table}}{\text{rate of feed}}$$

$$t_h = \frac{L}{s'}$$

The total travel or milling table travel depends on the length of the workpiece, the type of cutter and the method of milling applied.

### Travel L

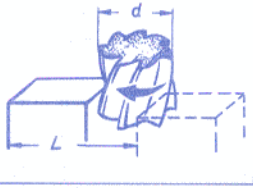



Slab milling

Roughing and finishing

$L$ = Length of workpiece + run on + over run

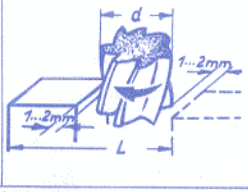
$L = l + a + u$




Travel $L$ at face milling

Roughing

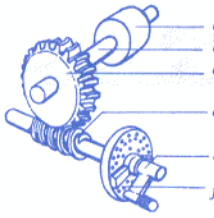
$L = l + \frac{d}{2} + 2$




Finishing

$L = l + d + 4$

## Simple indexing


a = workpiece
b = indexing spindle
c = worm wheel (mostly 40 teeth)
d = single start worm
e = index crank
f = index plate (remains stationary)

Usual numbers of holes on the hole circle

| | | | | | | |
|---|---|---|---|---|---|---|
| I : | 15 | 16 | 17 | 18 | 19 | 20 |
| II : | 21 | 23 | 27 | 29 | 31 | 33 |
| III: | 37 | 39 | 41 | 43 | 47 | 49 |

To turn the workpiece once, one must turn the index crank 40 times.

For $T$ divisions, $\frac{40}{T}$ turns are required to move through one division. It is:

$$\text{Number of crank turns for one division} = \frac{\text{number of teeth (mostly 40)}}{\text{number of divisions}}$$

$$\boxed{n_k = \frac{40}{T}}$$

Example: $T = 16$, $Z$ (teeth) $= 40$

$$n_k = \frac{Z}{T} = \frac{40}{16} = 2\,\frac{8}{16} = \text{no. of holes}$$

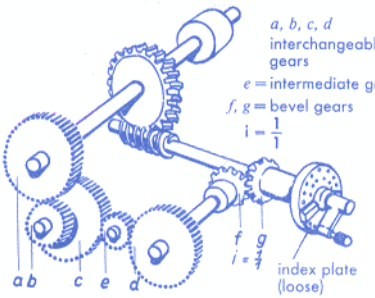
2 full crank turns and 8 more holes on the 16 hole circle

Example: $T = 45$, $Z$ (teeth) $= 40$

$$n_k = \frac{Z}{T} = \frac{40}{45} = \frac{8}{9} = \text{extended to an existing hole circle } \frac{8}{9} = \frac{8 \cdot 2}{9 \cdot 2} = \frac{16}{18}$$

16 holes on the 18 hole circle of

## Differential indexing




Differential indexing is possible only when a horizontal and levelled indexing spindle is used. It is applied where the simple indexing cannot be carried out.

The indexing spindle creates a lead or lag motion of the index disc over the changeable gears, which must be loose in case of differential indexing method.

$T$ = Number of divisions (number of divisions produced as a result of one complete rotation of workpiece)

$T'$ = Substitute number for $T$ ($T'$ close $T$ is so to be chosen that it can also be used in the simple indexing method).

$$\text{Number of crank turns for one division} = \frac{\text{number of teeth (mostly 40)}}{\text{substitute no. of divisions}}$$

$$\boxed{n_K = \frac{40}{T'}}$$

Ratio of number of teeth in the interchangeable gears = number of crank turns · (substitute no. of divisions – no. of divisions)

| No. of teeth of the interchangeable gears | | | | | | |
|---|---|---|---|---|---|---|
| 24 | 24 | 28 | 32 | 36 | 40 | 44 |
| 48 | 56 | 64 | 72 | 86 | 100 | |

$$\boxed{Z_W = \frac{40}{T'} \cdot (T' - T)}$$

If $T' > T$ the crank and disc must move in the same direction.
If $T' < T$ the crank and disc must move in opposite direction.

Example: $T = 53$, $Z = 40$

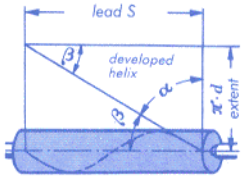
$T' = 56$ crank turns $n_k = \frac{40}{56} = \frac{15}{21}$ 15 holes on the hole circle 21

Changeable gears $Z_w = \frac{40}{T'} \cdot (T' - T) = \frac{15}{21} \cdot 3 = \frac{45}{21} = \frac{9}{3} \cdot \frac{5}{7} = \frac{72}{24} \cdot \frac{40}{56}$

Changeable gears: $Z_a = 72$; $Z_b = 24$; $Z_c = 40$; $Z_d = 56$

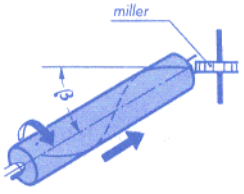
## Helical milling

During helical milling. (milling of grooves of larger lead) the workpiece moves in a longitudinal direction and rotates simultaneously. Both movement are governed by the table feed screw. It moves the machine table in a longitudinal direction and at the same time the indexing spindle is operated by a set of change gears. The index plate must be unlocked, i. e. rotatable. The milling table must be turned by a setting angle $\beta$.




Nomenclature

- $S$ lead on the workpiece (lead of helix)
- $s$ lead of the table screw (thread pitch)
- $d$ diameter of workpiece
- $a$ lead angle of helix
- $\beta$ setting angle of the table. ($\beta = 90° - \alpha$)
- $n_k$ Number of crank turns for a complete rotation of the workpiece ($i = n_k : 1 = 40 : 1$)




Lead $S = \tan \alpha \cdot \pi \cdot d$

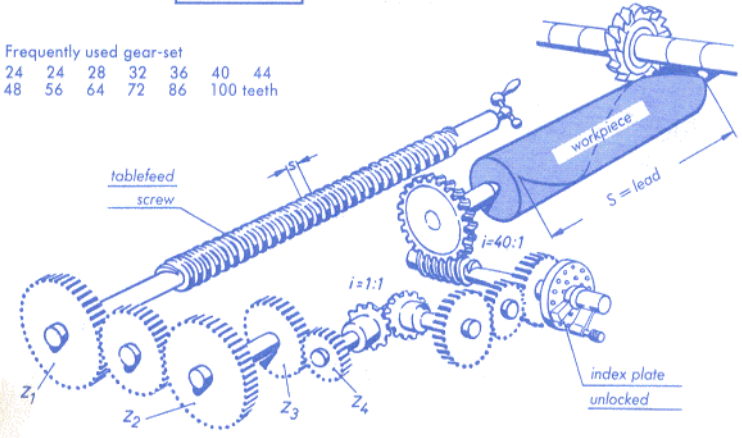
Lead angle $\tan \alpha = \dfrac{S}{\pi \cdot d}$

Setting angle of table $\boxed{\beta = 90° - \alpha}$ or $\boxed{\tan \beta = \dfrac{\pi \cdot d}{S}}$

Ratio of the changeable gears $\boxed{\dfrac{Z_1 \cdot Z_3}{Z_2 \cdot Z_4} = \dfrac{s \cdot n_k}{S}}$ $= \dfrac{\text{lead of the table screw} \cdot \text{number of crank turns (40)}}{\text{lead of the helix to be developed in workpiece}}$

Frequently used gear-set

| | | | | | | |
|---|---|---|---|---|---|---|
| 24 | 24 | 28 | 32 | 36 | 40 | 44 |
| 48 | 56 | 64 | 72 | 86 | 100 | teeth |




**Example:** $d = 40$ mm; $S = 450$ mm; $s = 6$ mm; $n_g = 40$

Solution: Table angle: $\tan \beta = \dfrac{\pi \cdot d}{S} = \dfrac{3.14 \cdot 40}{450} = 0.2796$; $\beta = 15° 31'$

Gears: $\dfrac{Z_1 \cdot Z_3}{Z_2 \cdot Z_4} = \dfrac{s \cdot n_k}{S} = \dfrac{6 \cdot 40}{450} = \dfrac{2 \cdot 4}{5 \cdot 3} = \dfrac{40 \cdot 32}{100 \cdot 24}$

**Check:**

$S = \dfrac{Z_2 \cdot Z_4 \cdot s \cdot n_k}{Z_1 \cdot Z_3}$

$= \dfrac{100 \cdot 24 \cdot 6 \cdot 40}{40 \cdot 32}$

$= 450$ mm

**Example:** $d = 42$ mm; $S = 26\,1/4'' \approx 667$ mm; $s = 4$ starts on $1'' = 1/4''$

Solution: Table angle: $\tan \beta = \dfrac{\pi \cdot d}{S} = \dfrac{3.14 \cdot 42}{667} = 0.1977$; $\beta = 10° 11'$

Gears: $\dfrac{Z_1 \cdot Z_3}{Z_2 \cdot Z_4} = \dfrac{s \cdot n_k}{S} = \dfrac{1/4'' \cdot 40}{105} = \dfrac{1 \cdot 40 \cdot 4}{4 \cdot 105} = \dfrac{8}{21} = \dfrac{2 \cdot 4}{3 \cdot 7} = \dfrac{24 \cdot 32}{36 \cdot 56}$

**Check:**

$S = \dfrac{Z_2 \cdot Z_4 \cdot s \cdot n_k}{Z_1 \cdot Z_3}$

$= \dfrac{36 \cdot 56 \cdot 1 \cdot 40}{24 \cdot 32 \cdot 4}$

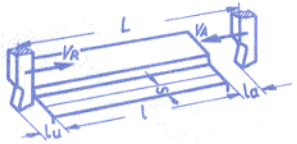
$= \dfrac{210}{8} = 26\,1/4''$

# Planing

## Cutting speed and feed

| | Tools made of | steel St 37 | steel St 60 | steel cast | grey cast iron | red brass | light metal |
|---|---|---|---|---|---|---|---|
| | | Cutting speed $v$ in m/min | | | | | |
| Roughing ▽ | Tool steel | 10...15 | 8...12 | 9...12 | 8...12 | 15...20 | – |
| | High speed steel | 15...20 | 12...16 | 12...16 | 12...16 | 20...25 | 30...35 |
| Finishing ▽▽ | Tool steel | 15...20 | 12...16 | 12...16 | 14...18 | 20...25 | – |
| | High speed steel | 20...25 | 16...20 | 16...20 | 18...22 | 30...40 | 50...60 |
| | | Feed in mm/stroke | | | | | |
| | Tool steel | 69 | | 0.2... 6 | | | – |
| | High Speed steel | | | 0.6...12 | | | 0.1...1 |

## Calculating the machining time




$L$ = Stroke length = workpiece length $l$ (in mm) + overrun $la$ and $lu$

$s$ = Feed per double stroke in mm

$V_A$ = Cutting speed in m/min

$V_R$ = Return stroke speed in m/min

| | | |
|---|---|---|
| Time for working stroke | $t_A = \frac{\text{length of stroke}}{\text{cutting speed}}$ | $t_A = \frac{L}{V_A \cdot 1000}$ in min |
| Time for return stroke | $t_R = \frac{\text{length of stroke}}{\text{return stroke speed}}$ | $t_R = \frac{L}{V_R \cdot 1000}$ in min |
| Time for one double stroke | $t$ = working stroke time + return stroke time | $t = \frac{L}{V_A \cdot 1000} + \frac{L}{V_R \cdot 1000}$ |
| No. of required double strokes | $Z = \frac{\text{width of workpiece}}{\text{Feed}}$ | $Z = \frac{b}{s}$ |

Required machining time $t_h$ = Number of double strokes · time taken by one double stroke

$$t_h = \frac{b}{s} \cdot \left( \frac{L}{V_A \cdot 1000} + \frac{L}{V_R \cdot 1000} \right) \text{ in min} \quad \text{or} \quad t_h = \frac{b}{s} \cdot \frac{2L}{V_m \cdot 1000} \text{ in min}$$

Average speed $V_m = \frac{2 V_A \cdot V_R}{V_A + V_R}$ = (m/min)

When $n$, the number of double strokes per min is known, the average speed $V_m$ can be calculated using the formula

$$V_m = \frac{2 \cdot L \cdot n}{1000} \text{ (m/min)}$$

**Example:** Width of workpiece $b = 200$ mm, Length of workpiece plus over travel $L = 400$ mm
$V_A = 10$ m/min $V_R = 20$ m/min $s = 5$ mm

$$t_h = \frac{b}{s} \cdot \left( \frac{L}{V_A \cdot 1000} + \frac{L}{V_R \cdot 1000} \right) = \frac{200}{5} \cdot \left( \frac{400}{10000} + \frac{400}{20000} \right) = \frac{200}{5} \cdot \frac{1200}{20000} = 2.4 \text{ min}$$

# Grinding

## Hardness and granulation of the grinding wheel

**Hardness** of the grinding wheel is the hardness of the bonding agent

Bonding agent (determines hardness of the grinder)

Abrasive grain (grinding agent)

**Granulation** is the grain size sequence

No. 8 (2.4 mm)

No. 30 (0.6 mm)

The sieve is used to separate the grains according to their sizes

The grains are coded according to the designation (no.) of the sieve

| Hardness of the grinding wheel | Hardness code | | | | Type of grain | Granulation code | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| very soft | E | F | G | | very coarse | 8 | 10 | 12 | | |
| soft | H | I | J | K | coarse | 14 | 16 | 18 | 20 | 24 |
| medium | L | M | N | O | medium | 30 | 36 | 46 | 50 | 60 |
| hard | P | Q | R | S | fine | 70 | 80 | 100 | 120 | |
| very hard | T | U | V | W | very fine | 150 | 200 | 240 | | |
| extremely hard | X | Y | Z | | fine as dust | 280 | 320 | 400 | 500 | 600 |

## Materials to be ground and abrasives

| | |
|---|---|
| Tough materials and materials with a strength above 340 N/mm²<br>E.g. hardened and annealed steels, malleable cast iron, cast steel | **Corundum disc**<br>(aluminium oxide) |
| Soft and brittle materials with a strength upto 340 N/mm²<br>E.g. grey cast iron, brass, soft bronze copper, aluminium, plastics | **Carborundum disc**<br>(silicate carbide) |

## Modes of grinding and binding materials

| | |
|---|---|
| All modes of grinding and materials | **Ceramic binding**<br>(sensitive to impact hammering) |
| Surface grinding with large contact surface, plain grinding<br>Thin and heat sensitive workpieces<br>E.g. sharpening of cutters and fine precision tool work | **Silicate binding**<br>(low heat generation) |
| High quality finish of chill casting<br>E.g. cast and steel rollers, hardened steel cams, aluminium pistons | **Shellac and rubber binding**<br>(elastic bindings) |

## Materials and porosity of grinding wheels

| | |
|---|---|
| Well finished grinding.<br>E.g. hard and brittle materials, small contact surface of wheel and workpiece | **Dense structure**<br>(low porosity) |
| Rough grinding<br>E.g. soft and lubricating materials (synthetic resins, hard metals, light metal) | **Coarse structure**<br>(high porosity) |

| Materials and hardness of grinding wheel | Material and grain size |
|---|---|
| Soft material – hard wheels<br>Hard materials – soft wheels | Soft material – coarse grain<br>Hard material – fine grain |

## Peripheral speeds of the grinding wheel

| Grinding Process | Pheripheral speed | |
|---|---|---|
| Cylindrical grinding | 25...30 m/s | For steel use the higher values. |
| Internal grinding | 15...20 m/s | |
| Face grinding | 20...25 m/s | For grey cast iron use the lower values. |
| Tool grinding | 18...20 m/s | |
| Cutting-off grinding | ...80 m/s | |

### Longitudinal feed *s*

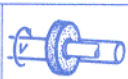
Longitudinal feed *s* per revolution of the workpiece in fractions of the breadth of the wheel *b*

| | Cylindrical grinding | | Internal grinding | |
|---|---|---|---|---|
| | Steel | Grey cast iron | Steel | Grey cast iron |
| Rough grinding | ⅔ ... ¾ | ¾ ... ⅚ | ½ ... ¾ | ⅔ ... ⅘ |
| Finish grinding | ¼ ... ⅓ | ⅓ ... ½ | ⅛ ... ¼ | ¼ ... ⅓ |

### Depth of cut

| Material | Rough grinding | Finish grinding |
|---|---|---|
| Steel | 0.01 mm ... 0.06 mm | 0.005 mm ... 0.01 mm |

### Pheripheral speed of the workpiece; Hardness and coarseness of the grinding wheel

| Material | Process | Cylindrical grinding | | Internal grinding | | Face grinding |
|---|---|---|---|---|---|---|
| | | Peripheral speed *v* m/min |  Grain/Hardness | Peripheral speed *v* m/min | Grain/Hardness | Grain/Hardness |
| Soft steel | rough gr.<br>finish gr. | 12...15<br>9...12 | 46 L...M | 16...21<br>– | 45...50 J...O | 30...60 J |
| Hardened steel | rough gr.<br>finish gr. | 14...16<br>9...12 | 46 K | –<br>18...23 | 46 K...60 H | 30...60 H ...K |
| Grey cast iron | rough gr.<br>finish gr. | 12...15<br>9...12 | 46 K | –<br>18...23 | 40...46 K...M | 16...30 J...K |
| Brass | rough gr.<br>finish gr. | 18...20<br>14...16 | 36 K...46 J | –<br>25...30 | 36 K...46 J | – |
| Aluminium | rough gr.<br>finish gr. | 40...50<br>28...35 | 30 K...40 J | –<br>32...35 | 30 H | – |

## Number of revolutions *n* for grinding wheels

| Grinding wheel Ø mm | Peripheral speed in m/sec 15 m | 20 m | 25 m | 30 m | 35 m | Grinding wheel Ø mm | Peripheral speed in m/sec 15 m | 20 m | 25 m | 30 m | 35 m |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | rpm of the wheel | | | | | | rpm of the wheel | | | | |
| 10 | 28600 | 38200 | 47700 | 57300 | 66800 | 130 | 2200 | 2950 | 3670 | 4400 | 5150 |
| 15 | 19100 | 25500 | 31800 | 38200 | 44600 | 150 | 1900 | 2550 | 3200 | 3800 | 4450 |
| 20 | 14300 | 19100 | 23900 | 28600 | 33400 | 175 | 1635 | 2200 | 2730 | 3270 | 3800 |
| 25 | 11500 | 15300 | 19100 | 23000 | 26750 | 200 | 1440 | 1910 | 2390 | 2875 | 3350 |
| 30 | 9500 | 12700 | 15900 | 19100 | 22200 | 225 | 1275 | 1700 | 2100 | 2550 | 2975 |
| 35 | 8100 | 10900 | 13600 | 16300 | 19100 | 250 | 1150 | 1525 | 1900 | 2300 | 2675 |
| 40 | 7160 | 9550 | 11940 | 14320 | 16700 | 275 | 1030 | 1400 | 1700 | 2060 | 2400 |
| 45 | 6300 | 8490 | 10600 | 12740 | 14860 | 300 | 950 | 1275 | 1590 | 1900 | 2230 |
| 50 | 5730 | 7650 | 9550 | 11450 | 13400 | 350 | 820 | 1090 | 1370 | 1640 | 1900 |
| 60 | 4750 | 6350 | 7950 | 9950 | 11100 | 400 | 725 | 960 | 1200 | 1450 | 1675 |
| 65 | 4400 | 5900 | 7350 | 8800 | 10300 | 450 | 635 | 850 | 1060 | 1275 | 1485 |
| 70 | 4050 | 5450 | 6800 | 8150 | 9550 | 500 | 575 | 770 | 960 | 1150 | 1340 |
| 75 | 3825 | 5100 | 6380 | 7650 | 9000 | 550 | 515 | 700 | 850 | 1030 | 1200 |
| 80 | 3580 | 4775 | 5970 | 7160 | 8350 | 600 | 475 | 640 | 800 | 950 | 1110 |
| 90 | 3185 | 4245 | 5300 | 6370 | 7430 | 650 | 440 | 590 | 730 | 875 | 1030 |
| 100 | 2865 | 3825 | 4775 | 5730 | 6700 | 700 | 405 | 540 | 675 | 810 | 950 |
| 115 | 2490 | 3320 | 4150 | 4980 | 5815 | 750 | 380 | 510 | 635 | 765 | 890 |
| 125 | 2300 | 3015 | 3800 | 4600 | 5300 | 800 | 360 | 475 | 600 | 715 | 835 |

## Number of revolutions *n* for workpieces

| Workpiece Ø mm | Peripheral speed of the workpiece in m/min 6 m | 8 m | 10 m | 12 m | 15 m | 18 m | 20 m | 24 m | 28 m | 32 m |
|---|---|---|---|---|---|---|---|---|---|---|
| | rpm of workpiece | | | | | | | | | |
| 5 | 382 | 510 | 636 | 764 | 956 | 1148 | 1280 | 1528 | 1784 | 2038 |
| 8 | 238 | 318 | 398 | 477 | 597 | 716 | 797 | 955 | 1114 | 1273 |
| 10 | 191 | 255 | 318 | 382 | 478 | 574 | 640 | 764 | 892 | 1019 |
| 12 | 159 | 212 | 265 | 318 | 398 | 477 | 531 | 637 | 743 | 849 |
| 14 | 136 | 182 | 227 | 273 | 341 | 409 | 455 | 546 | 637 | 728 |
| 16 | 119 | 159 | 199 | 239 | 298 | 358 | 398 | 477 | 557 | 637 |
| 18 | 106 | 141 | 177 | 212 | 265 | 318 | 354 | 424 | 495 | 566 |
| 20 | 95 | 128 | 159 | 191 | 239 | 287 | 319 | 382 | 446 | 509 |
| 22 | 87 | 115 | 145 | 174 | 217 | 260 | 289 | 347 | 405 | 459 |
| 25 | 76 | 102 | 127 | 153 | 190 | 229 | 255 | 306 | 357 | 408 |
| 28 | 68 | 99 | 114 | 136 | 171 | 205 | 228 | 273 | 318 | 364 |
| 32 | 59 | 79 | 99 | 119 | 149 | 179 | 199 | 239 | 279 | 318 |
| 36 | 53 | 71 | 88 | 106 | 132 | 159 | 177 | 212 | 247 | 283 |
| 40 | 47 | 63 | 79 | 95 | 119 | 143 | 159 | 191 | 223 | 254 |
| 45 | 42 | 56 | 70 | 85 | 106 | 127 | 141 | 170 | 198 | 226 |
| 50 | 38 | 51 | 63 | 76 | 95 | 115 | 127 | 153 | 178 | 204 |
| 56 | 34 | 45 | 57 | 68 | 85 | 102 | 114 | 136 | 159 | 182 |
| 63 | 30 | 40 | 51 | 61 | 76 | 99 | 101 | 121 | 141 | 162 |
| 70 | 27 | 36 | 45 | 55 | 68 | 82 | 91 | 109 | 127 | 145 |
| 80 | 23 | 31 | 39 | 47 | 59 | 71 | 79 | 95 | 111 | 125 |
| 90 | 21 | 28 | 35 | 42 | 53 | 63 | 71 | 85 | 99 | 112 |
| 100 | 19 | 25 | 31 | 38 | 47 | 57 | 63 | 76 | 89 | 102 |
| 110 | 17 | 23 | 29 | 35 | 43 | 52 | 58 | 69 | 81 | 93 |
| 125 | 15 | 20 | 25 | 30 | 38 | 45 | 51 | 61 | 71 | 81 |
| 140 | 13 | 18 | 23 | 27 | 34 | 41 | 45 | 55 | 64 | 73 |
| 160 | 12 | 16 | 19 | 24 | 29 | 36 | 39 | 48 | 56 | 64 |

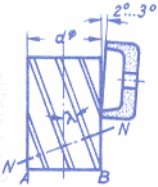
## Setting-up $h$ for sharpening of spiral fluted cutters

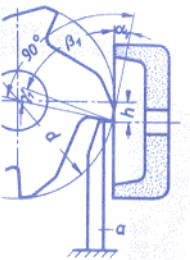
Grinding spindle and lever stop $a$ are lowered by the setting-up $h$ corresponding to the clearance angle $\alpha$

The cup wheel is set purposely at 2...3 deg inclination.

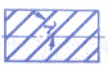
$d$ = diameter of cutter
$\lambda$ = helix angle of the helix to the cutter axis
$\alpha$ = effective clearance angle, measured perpendicular to the cutter (in the plain N-N)

$\alpha_1$ = ineffective clearance angle, measured across the face of the cutter A-B



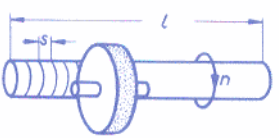




For tool steel and high speed steel: corundum wheel, normal grinding: 46...60, J...L, fine grinding: 60, K...M. For hard metals: silicon-carbide wheels, primary grinding 60 J Finishing: 80...100. G...H

| Helix angle $\lambda$ | Clearance angle $\alpha$ | Clearance angle $\alpha_1$ at the face plane | Diameter $d$ of cutter in mm | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 10 | 20 | 30 | 40 | 50 | 60 | 75 | 90 | 110 | 130 | 150 | 160 |
| | | | Setting-up $h$ in mm | | | | | | | | | | | |
| 20° | 3° | 2° 49' | 0.25 | 0.49 | 0.74 | 0.98 | 1.23 | 1.47 | 1.84 | 2.21 | 2.70 | 3.19 | 3.68 | 3.94 |
| | 4° | 3° 46' | 0.33 | 0.66 | 0.99 | 1.31 | 1.64 | 1.97 | 2.46 | 2.96 | 3.61 | 4.27 | 4.93 | 5.25 |
| | 5° | 4° 42' | 0.41 | 0.82 | 1.23 | 1.64 | 2.05 | 2.46 | 3.07 | 3.69 | 4.51 | 5.33 | 6.14 | 6.55 |
| | 6° | 5° 38' | 0.49 | 0.98 | 1.47 | 1.96 | 2.45 | 2.94 | 3.68 | 4.42 | 5.40 | 6.38 | 7.36 | 7.85 |
| | 7° | 6° 35' | 0.57 | 1.15 | 1.72 | 2.29 | 2.87 | 3.44 | 4.30 | 5.16 | 6.30 | 7.45 | 8.60 | 9.17 |
| | 8° | 7° 31' | 0.65 | 1.31 | 1.96 | 2.62 | 3.27 | 3.92 | 4.90 | 5.88 | 7.19 | 8.50 | 9.81 | 10.47 |
|  45° | 3° | 2° 7' | 0.18 | 0.37 | 0.55 | 0.74 | 0.92 | 1.11 | 1.38 | 1.66 | 2.03 | 2.40 | 2.77 | 2.95 |
| | 4° | 2° 50' | 0.25 | 0.49 | 0.74 | 0.99 | 1.24 | 1.48 | 1.85 | 2.22 | 2.72 | 3.21 | 3.71 | 3.95 |
| | 5° | 3° 32' | 0.31 | 0.62 | 0.92 | 1.23 | 1.54 | 1.85 | 2.31 | 2.77 | 3.39 | 4.00 | 4.61 | 4.92 |
| | 6° | 4° 15' | 0.37 | 0.74 | 1.11 | 1.48 | 1.85 | 2.22 | 2.78 | 3.33 | 4.08 | 4.82 | 5.56 | 5.93 |
| | 7° | 4° 58' | 0.43 | 0.87 | 1.30 | 1.73 | 2.16 | 2.60 | 3.24 | 3.89 | 4.76 | 5.63 | 6.49 | 6.93 |
| | 8° | 5° 40' | 0.49 | 0.99 | 1.48 | 1.97 | 2.47 | 2.96 | 3.70 | 4.44 | 5.43 | 6.42 | 7.40 | 7.90 |
| 60° | 3° | 1° 30' | 0.13 | 0.26 | 0.39 | 0.52 | 0.65 | 0.78 | 0.98 | 1.18 | 1.44 | 1.70 | 1.96 | 2.10 |
| | 4° | 2° | 0.17 | 0.35 | 0.52 | 0.70 | 0.87 | 1.05 | 1.31 | 1.57 | 1.92 | 2.27 | 2.62 | 2.79 |
| | 5° | 2° 30' | 0.22 | 0.44 | 0.65 | 0.87 | 1.09 | 1.31 | 1.64 | 1.96 | 2.40 | 2.83 | 3.27 | 3.49 |
| | 6° | 3° | 0.26 | 0.52 | 0.79 | 1.05 | 1.31 | 1.57 | 1.96 | 2.36 | 2.88 | 3.40 | 3.93 | 4.19 |
| | 7° | 3° 31' | 0.31 | 0.61 | 0.92 | 1.23 | 1.53 | 1.84 | 2.30 | 3.76 | 3.37 | 3.99 | 4.60 | 4.91 |
| | 8° | 4° 1' | 0.35 | 0.70 | 1.05 | 1.40 | 1.75 | 2.10 | 2.63 | 3.15 | 3.85 | 4.55 | 5.25 | 5.60 |

## Machining time in grinding

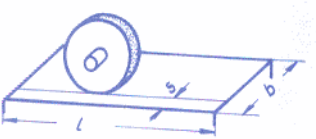
### Machining time for external and internal grinding.




$l$ = length of workpiece mm
$s$ = feed in mm/turn of workpiece
$n$ = r.p.m. of the workpiece
$i$ = number of cuts

$$th = \frac{l \cdot i}{n \cdot s}$$ in min

### Machining time for surface grinding.




$l$ = length of workpiece mm
$b$ = breadth of workpiece
$v$ = speed of table m/min
$s$ = feed mm/stroke

$$th = \frac{l \cdot b \cdot i}{v \cdot 1000 \cdot s}$$ in min

# Processing of synthetic materials

| Method of processing | Synthetic plastic materials<br>Type 11, 12, M. T, Z, S and K<br>(Bakelite, Faturan, Neoresit, Pollopas) | Laminated paper and fabrics<br>(Pertinax, Harex, Nonvotext, Resopal) |
|---|---|---|

**Filing**

▽ Roughing: rasp or milled files
▽▽ Finishing: common files

**Sawing**

Circular saw

| thickness of materials | 0.5...4 mm | 5...8 mm | 10 mm...and more |
|---|---|---|---|
| thickness of saw disc | 3 mm | 4 mm | 5 mm |

Tooth pitch ≈ 10 mm, teeth slightly crossed, hollow disc.

Cutting speed $v = 50$ m/s manual feed

**Drilling**

Point angle 90...116°, for thin walled workpieces 50°.
Flute angle 60°
Cutting speed $v = 70$ m/min
Feed $s = 0.2...0.3$ mm/rev

| Drilling of hard metals | point angle | rake angle |
|---|---|---|
| parallel to the fabric | 70° | 0...2° |
| Perpendicular to the fabric | 100...110° | 0...12° |

Cutting speed $v = 60...90$ m/min

Feed $s = 0.05...0.2$ mm/rev

Polished hard metal cutting.
Sharp cutting edges to be set in the material carefully to avoid damaging the periphary.
Lift drills for cooling purpose, with deep holes use compressed air to cool the drill.
Put wood or hard fabric at the point where the drill point is first to leave the material.
Dip drill in mineral oil to get smooth holes. Chips and vapour should be sucked out immediately.

**Planing**

Hard metal cutting edges, sharp and lapped
Cutting speed $v = 10...20$ m/min, feed $s = 0.2...0.8$ mm

**Turning**

Clearance angle $\alpha = 8°$ Rake angle $\gamma = 15°$

| | ▽ Roughing | ▽▽ Finishing | | Hard metal ▽ Roughing | Hard metal ▽▽ Finishing |
|---|---|---|---|---|---|
| $v$ m/min | 80...200 | 200...300 | $v$ m/min | 100...200 | 200...300 |
| $s$ mm/rev | 0.3...0.5 | 0.1...0.3 | $s$ mm/rev | 0.2...0.5 | 0.1...0.3 |
| Depth of cut | 3...5 mm | 2 mm | Depth of cut | 3...5 mm | 2 mm |

Place the cutter exactly in the centre.
Round off point of cutting edge, radius of curvature 1.5...2 mm.
Remove the chips by suction or exhaustion.

**Milling**

Hard metal clearance angle $\alpha = 20°$ rake angle $\gamma = 20...25°$
Number of teeth: 1/2...2/3 of the number of teeth used in metal milling.
Cutting if possible with long cuts.

| | |
|---|---|
| Cutting speed $v = 300$ m/min<br>feed $s = 0.5...0.8$ mm/rev. | Cutting speed $v = 120...250$ m/min<br>feed $s = 0.5...0.8$ mm/rev. |

**Thread cutting**

Taps with wide flutes. Coat with wax or grease for lubrication.

| | |
|---|---|
| Normal screw steel (high speed steel) | High speed steel $v \approx 20...40$ m/min<br>Milling gives a better finish than turning. |

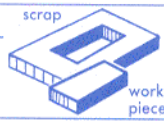
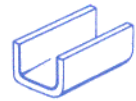
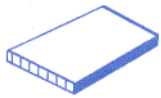
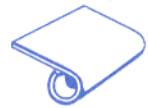
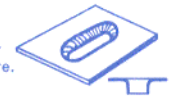
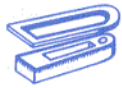
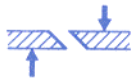
**Grinding**

Belt grinding machine $v \approx 6$ m/s.
Plate grinding machine, grinding machine using sand paper $v \approx 25$ m/s.
Surface and cylindrical grinding machine: use water as coolant.
Fine grinding: use silicon carbide. Grain size 60.
Rough grinding: use grain 20.

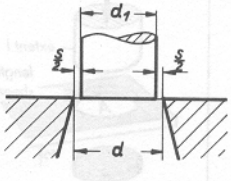
**Cutting**

Upto 3 mm thickness possible. For thicker material warm up the material.

## Cutting and punching

| Cutting | Forming |
|---|---|
| **Blanking** | **Bending** |
| Total separation of a workpiece in a closed line. Producing an outer form.   | Forming by bending.  |
| **Shearing** | **Rolling** |
| Seperation not in a closed line. (Cutting in stripes and notches).  | Forming done by a bending die of seaming machine.  |
| **Slitting** | **Shaping** |
| Partial seperation (slitting). | Forming done between punch and die without sheet holding. |
| **Punching** | **Folding** |
| Complete separation (punched-out part is the waste material), creating an inner form. | Bending by using a pressing or drawing process. |
| **Trimming** | **Lancing** |
| Bringing the desired size on a workpiece which has been drawn and moulded. | Similar to lancing, however the opening is already there.  |
| **Trimming, Burring** | **Punching** |
| Cutting off excess stock. Trimming of moulded parts.  | Used to facilitate recesses. |
| **Shaving** | **Reshaping** |
| Re-cutting in opposite directions.  | Sharp pressing operated after a punching or drawing process. |
| **Lancing** | **Embossing** |
| Partial punching and drawing out of material. | Changing the thickness of the stock due to forming. The embossing process does not cause deformation on the other side. |

## Clearance between die and punch




Clearance consideration

Clearance = difference in diameter between the die and punch

$$s = d - d_1$$

$\frac{s}{2}$ = gap width

For blanking: plate maintains the specific size, the punch is smaller by the amount of the clearance.

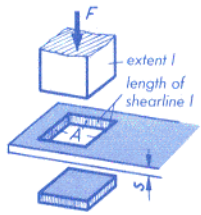
For punching: the punch maintains the specific size, the die plate is larger by the amount of the clearance.

| Thickness of sheet in mm | Clearance between punch and die | | | | | |
|---|---|---|---|---|---|---|
| | soft steel | moderately hard steel | hard steel | soft brass | hard brass | aluminium |
| 0.25 | 0.01 | 0.015 | 0.02 | 0.01 | 0.025 | 0.02 |
| 0.5 | 0.025 | 0.03 | 0.035 | 0.025 | 0.03 | 0.05 |
| 0.75 | 0.04 | 0.45 | 0.05 | 0.03 | 0.04 | 0.07 |
| 1.0 | 0.05 | 0.06 | 0.07 | 0.04 | 0.06 | 0.10 |
| 1.25 | 0.06 | 0.075 | 0.09 | 0.05 | 0.07 | 0.12 |
| 1.50 | 0.075 | 0.09 | 0.10 | 0.06 | 0.08 | 0.15 |
| 1.75 | 0.09 | 0.1 | 0.12 | 0.075 | 0.09 | 0.17 |
| 2.0 | 0.10 | 0.12 | 0.14 | 0.08 | 0.10 | 0.20 |
| 2.25 | 0.11 | 0.14 | 0.16 | 0.09 | 0.11 | 0.22 |
| 2.5 | 0.13 | 0.15 | 0.18 | 0.10 | 0.13 | 0.25 |
| 2.75 | 0.14 | 0.17 | 0.20 | 0.12 | 0.14 | 0.28 |
| 3.0 | 0.15 | 0.18 | 0.21 | 0.13 | 0.16 | 0.30 |
| 3.3 | 0.17 | 0.20 | 0.23 | 0.15 | 0.18 | 0.33 |
| 3.5 | 0.18 | 0.21 | 0.25 | 0.16 | 0.19 | 0.35 |
| 3.8 | 0.19 | 0.23 | 0.27 | 0.19 | 0.22 | 0.38 |
| 4.0 | 0.20 | 0.24 | 0.28 | 0.21 | 0.24 | 0.40 |
| 4.3 | 0.22 | 0.26 | 0.30 | 0.23 | 0.27 | 0.43 |
| 4.5 | 0.23 | 0.27 | 0.32 | 0.26 | 0.30 | 0.45 |
| 4.8 | 0.24 | 0.29 | 0.34 | 0.29 | 0.33 | 0.48 |
| 5.0 | 0.25 | 0.30 | 0.36 | 0.33 | 0.36 | 0.50 |

## Identification marks and symbols for cuts

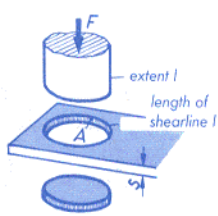
| Designation | Symbol | Identification mark | Designation | Symbol | Identification mark |
|---|---|---|---|---|---|
| Blade cut | Sm | | Die set | Sfs | |
| Free punch | S | | Progressive die (die set) | Sfsv | |
| Guided punch | Sf | | Combination die (die set) | Sfsg | |
| Progressive die (guided punch) | Sfv | | | | |

## Cutting force F




The cutting force depends on the shearing strength $\tau_B$ and the area to be cut $A$.
$A$ = length of shear line x thickness of sheet

$$F = A \cdot \tau_B \text{ in kg}$$
$$F = l \cdot s \cdot \tau_B$$

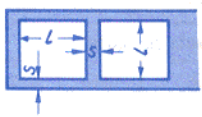



Cutting force = area to be cut x shearing strength

### Shearing and tensile strength of different materials

| Materials | Shearing strength $\tau_B$ N/mm² | Tensile strength $\tau_B$ N/mm² | Materials | Shearing strength $\tau_B$ N/mm² | Tensile strength $\tau_B$ N/mm² |
|---|---|---|---|---|---|
| St 13 | | 270 – 370 | Bronze sheet | 640 – 740 | |
| St 12 | | 270 – 410 | Copper sheet | 180 – 290 | 220 – 390 |
| Structural steel St 37 | | 360 – 440 | Brass sheet | 220 – 390 | |
| Structural steel St 42 | | 410 – 490 | Rolled Bronze | 310 – 590 | |
| St 50 | | 490 – 610 | Zinc | 120 – 200 | |
| St 60 | | 590 – 710 | Aluminium | 70 | 110 |
| St 70 | | 690 – 830 | Al Mg annealed | | 290 – 340 |
| Silicon steel | 440 – 640 | | Al Mn annealed | | 90 – 120 |
| Steel with 0.1 % C | 250 – 310 | | Al Cu Mg annealed | 160 – 240 | |
| 0.2 % C | 310 – 390 | | Al Mg Si annealed | | 110 – 150 |
| 0.3 % C | 350 – 470 | | Al Mg Mn annealed | | 180 – 200 |
| 0.4 % C | 440 – 550 | | Mg Mn annealed | | 190 – 230 |
| 0.6 % C | 550 – 710 | | Mg Zn annealed | | 250 – 270 |
| 0.8 % C | 710 – 880 | | Klingerite | 40 | |
| 1.0 % C | 780 – 1030 | | Synthetic resins | 90 | |

### Web and stem width



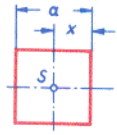

Widths of web and stem are determined by the thickness of the material to be cut and the length of the web (or cutting edge)

| Length of web in mm | Thickness of sheet im mm | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.5 | 0.75 | 1 | 1.25 | 1.5 | 1.75 | 2 | 2.25 | 2.5 | 3 | 3.5 | 4 |
| 10 | 1.5 | 1.2 | 1 | 1.4 | 1.5 | 1.8 | 2 | 2 | 2 | 2 | 2.5 | 2.5 |
| 50 | 2 | 1.7 | 1.75 | 1.9 | 2 | 2.2 | 2.5 | 2.8 | 3 | 3.5 | 3.7 | 4 |
| 100 | 3 | 2.4 | 2 | 2.4 | 2.5 | 2.7 | 3 | 3.2 | 3.5 | 4 | 4.2 | 4.5 |
| 150 | 3.5 | 2.9 | 2.5 | 2.9 | 3 | 3.2 | 3.5 | 3.7 | 4 | 4.5 | 4.7 | 5 |
| 250 | 4 | 3.4 | 3 | 3.4 | 3.5 | 3.7 | 4 | 4.2 | 4.5 | 5 | 5.2 | 5.5 |
| 350 | 4.5 | 3.9 | 3.5 | 3.9 | 4 | 4.2 | 4.5 | 4.7 | 5 | 5.5 | 5.7 | 6 |

## Position of centre of gravity $S$ for lines (for cutting tools)

$S$ lies on the intersection of the centre lines

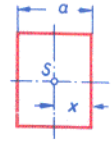
$$x = \frac{a}{2}$$




**Square**

$S$ lies on the intersection of the centre lines

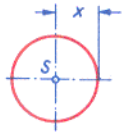
$$x = \frac{a}{2}$$




**Rectangle**

$S$ lies on the intersection of the centre lines

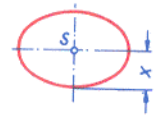
$$x = \frac{d}{2}$$




**Circle**

$S$ lies on the intersection of the axes

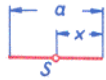
$$x = \frac{a}{2}$$




**Ellipse**

$S$ lies in the middle of the line

$$x = \frac{a}{2}$$



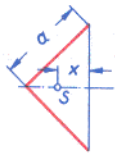

**Straight line**

The middle points of the sides of triangle are connected to each other $S$ is the centre of the inscribed circle

**Triangle**

$S$ lies on the bisecting line of the angle

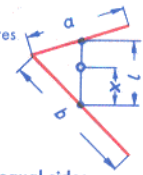
$$x = 0{,}707 \cdot \frac{a}{2}$$




**Right angle with equal sides**

$S$ lies on the connecting line of individual centres of gravity

$$x = \frac{a \cdot l}{a + b}$$




**Angle with unequal sides**

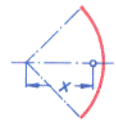
$S$ lies on the centre line

$$x = 0{,}637 \cdot r$$

**Semi-circle**

$S$ lies on the centre line

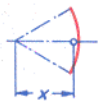
$$x = 0{,}9 \cdot r$$




**Quarter circle**

$S$ lies on the centre line

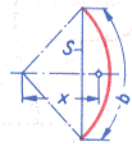
$$x = 0{,}955 \cdot r$$




**One sixth arc segment**

$S$ lies on the centre line

$$x = \frac{r \cdot s}{b}$$




**Arbitrary arc segment**

# Calculating the location of the centre of gravity

**Finding the centre of gravity for a punch** – blank: symmetrical

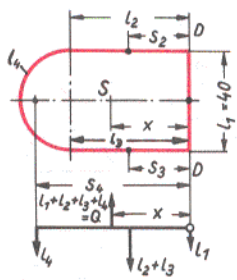
The shank of a press tool must be installed at the centre of gravity of the shearing lines
Calculation according to the law of moments

| | | | |
|---|---|---|---|
| Fulcrum | = | $D-D$ | arbitrary axis of rotation |
| Force | = | $l$ | length of the shearing line |
| Force arm | = | $s$ | distance of the individual centre of gravity from the axis of rotation |
| Load | = | $Q$ | sum of all the shearing lines $l_1 + l_2 + l_3 \ldots)$ |
| Load arm | = | $x$ | distance of the centre of gravity $S$ from the axis of rotation |

Force x force arm = load x load arm
Sum of moments of all forces = moment of centre force

$$\Sigma\, l \cdot s = Q \cdot x$$

$$x = \frac{\Sigma l \cdot s}{Q}$$




**Example:**

$l_1 = 40$ mm $s_1 = 0$
$l_2 = 50$ mm $s_2 = 25$ mm
$l_3 = 50$ mm $s_3 = 25$ mm
$l_4 = 62.8$ mm $s_4 = 0.637 \cdot 20 + 50$
$Q = 202.8$ mm $= 62.7$ mm

$$x = \frac{\Sigma\, l \cdot s}{Q} = \frac{40 \cdot 0 + 50 \cdot 25 + 50 \cdot 25 + 62.8 \cdot 62.7}{202.8}$$

$x = 31.7$ mm

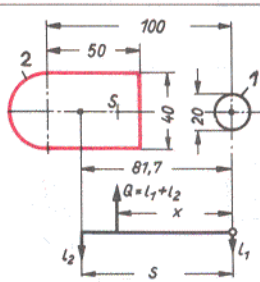
**Finding the centre of gravity for a tool using two punches** – blank: symmetrical

| | | |
|---|---|---|
| Fulcrum | = | centre of gravity of a punch (1) |
| Force | = | shearing line (circumference) of the other punch (2) |
| Force arm | = | distance between centres of gravity of both punches |
| Load | = | sum of shearing lines of punches (circumference) |
| Load arm | = | distance of the sought centre of gravity from the axis of rotation |

Force x force arm = load x load arm

$$l \cdot s = Q \cdot x$$

$$x = \frac{l \cdot s}{Q}$$




**Example:**

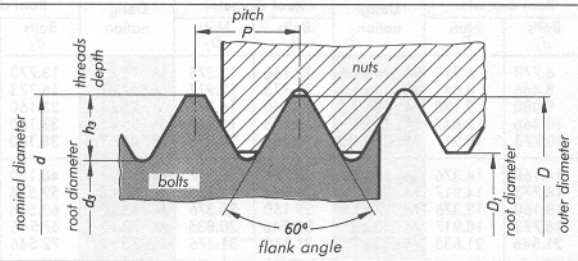
Centres of gravity of both punches are known
Shearing line (1) (circumference) $l_1 = 62.8$ mm
Shearing line (2) (circumference) $l_2 = 202.8$ mm
Distance between the centres of gravity $s = 81.7$ mm

$$x = \frac{l_2 \cdot s}{Q} = \frac{202.8 \cdot 81.7}{265.6} = 62.4 \text{ mm}$$

Jointing is the process of finishing by bringing together a number of solid bodies or a body with formless material.

## Screws and threads

### Metric ISO-threads [1] (standard threads)




| Bolts | | | | | | Nuts | | | Washers | |
|---|---|---|---|---|---|---|---|---|---|---|
| External thread Ø | | Root Ø | Root cross section | Pitch | Head height | Nut height | Width across flats | Width across corners | Outer Ø | Thick-ness |
| Series 1 | Series 2 | | | | | | | | | |
| d | d | $d_3$ | mm² | P | k | m | s | $e_1$ | $d_2$ | s |
| 1 | | 0.693 | 0.37 | 0.25 | – | 0.8 | 2.5 | 2.72 | – | – |
| 1.2 | | 0.893 | 0.62 | 0.25 | – | 1.0 | 3 | 3.29 | – | – |
| | 1.4 | 1.032 | 0.83 | 0.3 | – | 1.2 | 3 | 3.29 | – | – |
| 1.6 | | 1.170 | 1.07 | 0.35 | 1.1 | 1.3 | 3.2 | 3.48 | 4.5 | 0.3 |
| 2 | | 1.509 | 1.77 | 0.4 | 1.4 | 1.6 | 4 | 4.38 | 5 | 0.3 |
| 2.5 | | 1.948 | 2.96 | 0.45 | 1.7 | 2 | 5 | 5.51 | 6.5 | 0.5 |
| 3 | | 2.387 | 4.45 | 0.5 | 2 | 2.4 | 5.5 | 6.08 | 7 | 0.5 |
| | 3.5 | 2.764 | 5.98 | 0.6 | 2.4 | 2.8 | 6 | 6.64 | 8 | 0.5 |
| 4 | | 3.141 | 7.74 | 0.7 | 2.8 | 3.2 | 7 | 7.74 | 9 | 0.8 |
| 5 | | 4.019 | 12.6 | 0.8 | 3.5 | 4 | 8 | 8.87 | 10 | 1 |
| 6 | | 4.773 | 17.9 | 1 | 4 | 5 | 10 | 11.05 | 12.5 | 1.6 |
| 8 | | 6.466 | 32.8 | 1.25 | 5.5 | 6.5 | 13 | 14.38 | 17 | 1.6 |
| 10 | | 8.160 | 52.4 | 1.5 | 7 | 8 | 17 | 18.09 | 21 | 2 |
| 12 | | 9.853 | 76.2 | 1.75 | 8 | 10 | 19 | 21.10 | 24 | 2.5 |
| | 14 | 11.546 | 104 | 2 | 9 | 11 | 22 | 24.49 | 28 | 2.5 |
| 16 | | 13.546 | 143 | 2 | 10 | 13 | 24 | 26.75 | 30 | 3 |
| | 18 | 14.933 | 174 | 2.5 | 12 | 15 | 27 | 30.14 | 34 | 3 |
| 20 | | 16.933 | 224 | 2.5 | 13 | 16 | 30 | 33.53 | 37 | 3 |
| | 22 | 18.933 | 280 | 2.5 | 14 | 18 | 32 | 35.72 | 39 | 3 |
| 24 | | 20.319 | 324 | 3 | 15 | 19 | 36 | 39.98 | 44 | 4 |
| | 27 | 23.319 | 426 | 3 | 17 | 22 | 41 | 45.63 | | |
| 30 | | 25.706 | 519 | 3.5 | 19 | 24 | 46 | 51.28 | 56 | 4 |
| | 33 | 28.706 | 647 | 3.5 | 21 | 26 | 50 | 55.80 | 60 | 5 |
| 36 | | 31.093 | 760 | 4 | 23 | 29 | 55 | 61.31 | 66 | 5 |
| | 39 | 34.093 | 913 | 4 | 25 | 31 | 60 | 66.96 | 72 | 6 |
| 42 | | 36.479 | 1046 | 4.5 | 26 | 34 | 65 | 72.61 | 78 | 7 |
| | 45 | 39.479 | 1225 | 4.5 | 28 | 36 | 70 | 78.26 | 85 | 7 |
| 48 | | 41.866 | 1373 | 5 | 30 | 38 | 75 | 83.91 | 92 | 8 |
| | 52 | 45.866 | 1655 | 5 | 33 | 42 | 80 | 89.56 | 98 | 8 |

1) Metric ISO standard threads according to DIN 13 Pg. 1 (March 73)
Hexagonal nut according to DIN 934 (Apr. 68) size $e_1$ for model m
Hexagonal screws according to DIN 931 (Nov. 70)
Washers according to DIN 125 (May 68)
Designation of a metric thread of 20 mm thread diameter: M 20

# Metric ISO-threads

DIN 13 Pg.12 (Sept. 69)

Series for selection of fine pitch threads

| Series 1 | | | Series 2 | | | Series 3 | | |
|---|---|---|---|---|---|---|---|---|
| Designation | Root diameter | | Designation | Root diameter | | Designation | Root diameter | |
| | Bolts $d_3$ | Nuts $D_1$ | | Bolts $d_3$ | Nuts $D_1$ | | Bolts $d_3$ | Nuts $D_1$ |
| M 8x1 | 6.773 | 6.917 | M 14x1.5 | 12.160 | 12.376 | M 15x1 | 13.773 | 13.917 |
| M 10x1.25 | 8.466 | 8.647 | M 14x1 | 12.773 | 12.917 | M 17x1 | 15.773 | 15.917 |
| M 10x0.75 | 9.080 | 9.188 | M 18x1.5 | 16.160 | 16.376 | M 25x1.5 | 23.160 | 23.376 |
| M 12x1.25 | 10.466 | 10.647 | M 18x1 | 16.773 | 16.917 | M 35x1.5 | 33.160 | 33.376 |
| M 12x1 | 10.773 | 10.917 | M 22x1.5 | 20.160 | 20.376 | M 40x1.5 | 38.160 | 38.376 |
| M 16x1.5 | 14.160 | 14.376 | M 22x1 | 20.773 | 20.917 | M 50x1.5 | 48.160 | 48.376 |
| M 16x1 | 14.773 | 14.917 | M 27x2 | 24.546 | 24.835 | M 55x2 | 52.546 | 52.835 |
| M 20x1.5 | 18.160 | 18.376 | M 27x1.5 | 25.160 | 25.376 | M 65x2 | 62.546 | 62.835 |
| M 20x1 | 18.773 | 18.917 | M 33x2 | 30.546 | 30.835 | M 70x2 | 67.546 | 67.835 |
| M 24x2 | 21.546 | 21.835 | M 33x1.5 | 31.160 | 31.376 | M 75x2 | 72.546 | 72.835 |
| M 24x1.5 | 22.160 | 22.376 | M 39x3 | 35.319 | 35.752 | M 136x6 | 127.639 | 128.505 |
| M 30x2 | 27.546 | 27.835 | M 39x1.5 | 37.160 | 37.376 | M 135x2 | 132.546 | 132.835 |
| M 30x1.5 | 28.160 | 28.376 | M 45x3 | 41.319 | 41.752 | M 145x2 | 142.546 | 142.835 |
| M 36x3 | 32.319 | 32.752 | M 45x1.5 | 43.160 | 43.376 | M 155x3 | 151.319 | 151.752 |
| M 36x1.5 | 34.160 | 34.376 | M 52x3 | 48.319 | 48.752 | M 165x3 | 161.319 | 161.752 |
| M 42x3 | 38.319 | 38.752 | M 52x2 | 49.546 | 49.835 | M 230x6 | 222.639 | 223.505 |
| M 42x1.5 | 40.160 | 40.376 | M 60x4 | 55.093 | 55.670 | M 230x4 | 225.093 | 225.670 |
| M 48x3 | 44.319 | 44.752 | M 60x2 | 57.546 | 57.835 | M 270x6 | 262.639 | 263.505 |
| M 48x1.5 | 46.160 | 46.376 | M 68x4 | 63.402 | 63.670 | M 270x4 | 265.093 | 265.670 |
| M 56x4 | 51.093 | 51.670 | M 68x2 | 65.546 | 65.835 | M 290x6 | 282.639 | 283.505 |
| M 56x2 | 53.546 | 53.835 | M 76x6 | 68.639 | 69.505 | M 290x4 | 285.093 | 285.670 |
| M 64x4 | 59.093 | 59.670 | M 76x4 | 71.093 | 71.670 | | | |
| M 64x2 | 61.546 | 61.835 | M 76x2 | 73.546 | 73.835 | | | |
| M 72x6 | 64.639 | 65.505 | M 85x6 | 77.639 | 78.505 | | | |
| M 72x4 | 67.093 | 67.670 | M 85x4 | 80.093 | 80.670 | | | |
| M 72x2 | 69.546 | 69.835 | M 85x2 | 82.546 | 82.835 | | | |
| M 80x6 | 72.639 | 73.505 | M 95x6 | 87.639 | 88.505 | | | |
| M 80x4 | 75.093 | 75.670 | M 95x4 | 90.093 | 90.670 | | | |
| M 80x2 | 77.546 | 77.835 | M 95x2 | 92.546 | 92.835 | | | |
| M 90x6 | 82.639 | 83.505 | M 105x6 | 97.639 | 98.505 | | | |
| M 90x4 | 85.093 | 85.670 | M 105x4 | 100.093 | 100.670 | | | |
| M 90x2 | 87.546 | 87.835 | M 105x2 | 102.546 | 102.835 | | | |
| M 100x6 | 92.639 | 93.505 | M 115x6 | 107.639 | 108.505 | | | |
| M 100x4 | 95.093 | 95.670 | M 115x4 | 110.093 | 110.670 | | | |
| M 100x2 | 97.546 | 97.835 | M 115x2 | 112.546 | 112.835 | | | |
| M 110x6 | 102.639 | 103.505 | M 120x6 | 112.639 | 113.505 | | | |
| M 110x4 | 105.093 | 105.670 | M 120x4 | 115.093 | 115.670 | | | |
| M 110x2 | 107.546 | 107.835 | M 120x2 | 117.546 | 117.835 | | | |
| M 125x6 | 117.639 | 118.505 | M 130x6 | 122.639 | 123.505 | | | |
| M 125x4 | 120.093 | 120.670 | M 130x4 | 125.093 | 125.670 | | | |
| M 125x2 | 122.546 | 122.835 | M 130x2 | 127.546 | 127.835 | | | |
| M 140x6 | 132.639 | 133.505 | M 150x6 | 142.639 | 143.505 | | | |
| M 140x4 | 135.093 | 135.670 | M 150x4 | 145.093 | 145.670 | | | |
| M 140x2 | 137.546 | 137.835 | M 150x2 | 147.546 | 147.835 | | | |
| M 160x6 | 152.639 | 153.505 | M 170x6 | 162.639 | 163.505 | | | |
| M 160x3 | 156.319 | 156.752 | M 170x3 | 166.319 | 166.752 | | | |
| M 180x6 | 172.639 | 173.505 | M 190x6 | 182.639 | 183.505 | | | |
| M 180x3 | 176.319 | 176.752 | M 190x3 | 186.319 | 186.752 | | | |
| M 200x6 | 192.639 | 193.505 | M 210x6 | 202.639 | 203.505 | | | |
| M 200x3 | 196.319 | 196.752 | M 210x4 | 205.093 | 205.670 | | | |
| M 220x6 | 212.639 | 213.505 | M 240x6 | 232.639 | 233.505 | | | |
| M 220x4 | 215.093 | 215.670 | M 240x4 | 235.093 | 235.670 | | | |
| M 250x6 | 242.639 | 243.505 | M 260x6 | 252.639 | 253.505 | | | |
| M 250x4 | 245.093 | 245.670 | M 260x4 | 255.093 | 255.670 | | | |
| M 280x6 | 272.639 | 273.505 | M 300x6 | 292.539 | 293.505 | | | |
| M 280x4 | 275.093 | 275.670 | M 300x4 | 295.093 | 295.670 | | | |

Note:

1) The standard threads DIN 13 Pg. 1 are preferred.

2) Designation for standard threads e.g. M 10

3) Designation for fine pitch thread e.g. M 10 x 0.75. (Nominal diameter x pitch).

4) Series I is preferred to series 2 and series 2 to series 3.

5) Root diameters for fine pitch thread according to

DIN 13 Pg. 4 (Apr. 70)
DIN 13 Pg. 5 (Apr. 70)
DIN 13 Pg. 6 (Sept. 70)
DIN 13 Pg. 7 (Sept. 70)
DIN 13 Pg. 8 (Sept. 70)
DIN 13 Pg. 9 (Sept. 70)
DIN 13 Pg. 10 (Sept. 70)

# Metric ISO-trapezoidal thread [1]

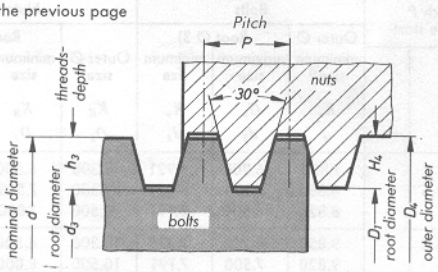
DIN 103
Aug. 70 Dec. 71

| Thread nominal - Ø | | Pitch $P$ Single start | | | Bolts | | | Nuts | | | Bolts Nuts |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Outer Ø | Root Ø 3) | | | Root Ø 4) | | |
| Series 1 | Series 2 | Preferred series | | | minimum size [2] | maximum size | minimum size | Outer Ø size | minimum size | maximum size | Depth of thread |
| | | | | | $K_w$ | $G_w$ | $K_w$ | $K_B$ | $K_B$ | $G_B$ | $h_3 = H_4$ |
| $d$ | $d$ | | | | $d$ | $d_3$ | $d_3$ | $D_1$ | $D_1$ | $D_1$ | |
| 8 | | 1.5 | | | 7.850 | 6.200 | 5.921 | 8.300 | 6.500 | 6.690 | 0.9 |
| | 9 | | 1.5 | | 8.850 | 7.200 | 6.921 | 9.300 | 7.500 | 7.690 | 0.9 |
| | 9 | 2 | | | 8.820 | 6.500 | 6.191 | 9.500 | 7.000 | 7.236 | 1.25 |
| 10 | | | 1.5 | | 9.850 | 8.200 | 7.921 | 10.300 | 8.500 | 8.690 | 0.9 |
| 10 | | 2 | | | 9.820 | 7.500 | 7.191 | 10.500 | 8.000 | 8.236 | 1.25 |
| | 11 | 2 | | | 10.820 | 8.500 | 8.191 | 11.500 | 9.000 | 9.236 | 1.25 |
| | 11 | | 3 | | 10.764 | 7.500 | 7.150 | 11.500 | 8.000 | 8.315 | 1.75 |
| 12 | | | 2 | | 11.820 | 9.500 | 9.179 | 12.500 | 10.000 | 10.236 | 1.25 |
| 12 | | 3 | | | 11.764 | 8.500 | 8.135 | 12.500 | 9.000 | 9.315 | 1.75 |
| | 14 | 2 | | | 13.820 | 11.500 | 11.179 | 14.500 | 12.000 | 12.236 | 1.25 |
| | 14 | 3 | | | 13.764 | 10.500 | 10.135 | 14.500 | 11.000 | 11.315 | 1.75 |
| 16 | | | 2 | | 15.820 | 13.500 | 13.179 | 16.500 | 14.000 | 14.236 | 1.25 |
| 16 | | 4 | | | 15.700 | 11.500 | 11.074 | 16.500 | 12.000 | 12.375 | 2.25 |
| | 18 | 2 | | | 17.820 | 15.500 | 15.179 | 18.500 | 16.000 | 16.236 | 1.25 |
| | 18 | 4 | | | 17.700 | 13.500 | 13.074 | 18.500 | 14.000 | 14.375 | 2.25 |
| 20 | | | 2 | | 19.820 | 17.500 | 17.179 | 20.500 | 18.000 | 18.236 | 1.25 |
| 20 | | 4 | | | 19.700 | 15.500 | 15.074 | 20.500 | 16.000 | 16.375 | 2.25 |
| | 22 | | 3 | | 21.764 | 18.500 | 18.135 | 22.500 | 19.000 | 19.315 | 1.75 |
| | 22 | 5 | | | 21.665 | 16.500 | 16.044 | 22.500 | 17.000 | 17.450 | 2.75 |
| | 22 | | | 8 | 21.550 | 13.000 | 12.424 | 23.000 | 14.000 | 14.630 | 4.5 |
| 24 | | | 3 | | 23.764 | 20.500 | 20.103 | 24.500 | 21.000 | 21.315 | 1.75 |
| 24 | | 5 | | | 23.665 | 18.500 | 18.019 | 24.500 | 19.000 | 19.450 | 2.75 |
| 24 | | | | 8 | 23.550 | 15.000 | 14.399 | 25.000 | 16.000 | 16.630 | 4.5 |
| | 26 | | 3 | | 25.764 | 22.500 | 22.103 | 26.500 | 23.000 | 23.315 | 1.75 |
| | 26 | 5 | | | 25.655 | 20.500 | 20.019 | 26.500 | 21.000 | 21.450 | 2.75 |
| | 26 | | | 8 | 25.550 | 17.000 | 16.399 | 27.000 | 18.000 | 18.630 | 4.5 |
| 28 | | | 3 | | 27.764 | 24.500 | 24.103 | 28.500 | 25.000 | 25.315 | 1.75 |
| 28 | | 5 | | | 27.665 | 22.500 | 22.019 | 28.500 | 23.000 | 23.450 | 2.75 |
| 28 | | | | 10 | 27.550 | 19.000 | 18.399 | 29.000 | 20.000 | 20.630 | 4.5 |
| | 30 | | 3 | | 29.764 | 26.500 | 26.103 | 30.500 | 27.000 | 27.315 | 1.75 |
| | 30 | 6 | | | 29.625 | 23.000 | 22.463 | 31.000 | 24.000 | 24.500 | 3.5 |
| | 30 | | | 10 | 29.470 | 19.000 | 18.350 | 31.000 | 20.000 | 20.710 | 5.5 |
| 32 | | | 3 | | 31.764 | 28.500 | 28.103 | 32.500 | 29.000 | 29.315 | 1.75 |
| 32 | | 6 | | | 31.625 | 25.000 | 24.463 | 33.000 | 26.000 | 26.500 | 3.5 |
| 32 | | | | 10 | 31.470 | 21.000 | 20.350 | 33.000 | 22.000 | 22.710 | 5.5 |
| | 34 | 6 | | | 33.625 | 27.000 | 26.463 | 35.000 | 31.000 | 31.315 | 3.5 |
| 36 | | 6 | | | 35.625 | 29.000 | 28.463 | 37.000 | 30.000 | 30.500 | 3.5 |
| | 38 | 7 | | | 37.575 | 30.000 | 29.431 | 39.000 | 31.000 | 31.560 | 4 |
| 40 | | 7 | | | 39.575 | 32.000 | 31.431 | 41.000 | 33.000 | 33.560 | 4 |
| | 42 | 7 | | | 41.575 | 34.000 | 33.431 | 43.000 | 35.000 | 35.560 | 4 |
| 44 | | 7 | | | 43.575 | 36.000 | 35.431 | 45.000 | 37.000 | 37.560 | 4 |
| | 46 | 8 | | | 45.550 | 37.000 | 36.368 | 47.000 | 38.000 | 38.630 | 4.5 |
| 48 | | 8 | | | 47.550 | 39.000 | 38.368 | 49.000 | 40.000 | 40.630 | 4.5 |
| | 50 | 8 | | | 49.550 | 41.000 | 40.368 | 51.000 | 42.000 | 42.630 | 4.5 |

1)...4) diagram and remarks on the next page

## Metric ISO-trapezoidal threads

Refer to the table in the previous page




Note:

1) Designation for single start thread, e. g. Tr 40 x 7 (nominal diameter x lead)
Selection series: Series 1 of the thread nominal diameters is preferred to series 2

As far as possible, the most preferred series out of the 3 should be used:
(e. g. Tr 10 x 2 is preferred to Tr 10 x 1.5).

Designation for multiple start threads: e.g. Tr 40 x 14 P7 (nominal diameter x $P_h$ of the multiple start thread. Letter $P$ for pitch and the pitch in mm).

Number of starts $= \frac{\text{lead } P_h}{\text{pitch } P} = \frac{14}{7}$ (2 start threads)

Preferred pitches as per DIN 103 Pg. 2 (Aug. 70). Depth of the threads according to DIN 103 Pg. 1 (Aug 70).

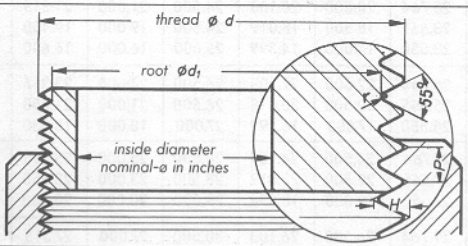
2) For the fits 4 *h* (maximum size of the bolt = nominal size). Maximum and minimum sizes of the bolts as per DIN 103 Pg. 7 (Oct. 72).

3) For the fits 7 *e*.

4) For the fits 4 *H* (maximum and minimum sizes for the nuts as per DIN 103 Pg. 5 (Oct. 72).

## Whitworth thread

DIN 259 (Juni 66)




Thread designation e. g. *R* ½

$P = \frac{25.4}{z}$

$r = 0.137 \cdot P$

$H = 0.960 \cdot P$

| Nominal-Ø (inside diameter in inches) | Bolts and nuts: Thread Ø $d$ | Bolts and nuts: Root Ø $d_1$ | Pitch $P$ | Number of start to an inch $z$ | Nominal-Ø (inside diameter in inches) | Bolts and nuts: Thread Ø $d$ | Bolts and nuts: Root Ø $d_1$ | Pitch $P$ | Number of start to an inch $z$ |
|---|---|---|---|---|---|---|---|---|---|
| R ⅛ | 9.73 | 8.57 | 0.91 | 28 | R 2 | 59.62 | 56.66 | 2.31 | 11 |
| R ¼ | 13.16 | 11.45 | 1.34 | 19 | (R 2 ¼) | 65.71 | 62.76 | 2.31 | 11 |
| R ⅜ | 16.66 | 14.95 | 1.34 | 19 | R 2 ½ | 75.19 | 72.23 | 2.31 | 11 |
| R ½ | 20.96 | 18.63 | 1.81 | 14 | (R 2 ¾) | 81.54 | 78.58 | 2.31 | 11 |
| (R ⅝) | 22.91 | 20.59 | 1.81 | 14 | R 3 | 87.89 | 84.93 | 2.31 | 11 |
| R ¾ | 26.44 | 24.12 | 1.81 | 14 | (R 3 ¼) | 93.98 | 91.03 | 2.31 | 11 |
| (R ⅞) | 30.20 | 27.88 | 1.81 | 14 | R 3 ½ | 100.33 | 97.37 | 2.31 | 11 |
| R 1 | 33.25 | 30.29 | 2.31 | 11 | (R 3 ¾) | 106.68 | 103.73 | 2.31 | 11 |
| R 1 ¼ | 41.91 | 38.95 | 2.31 | 11 | R 4 | 113.03 | 110.08 | 2.31 | 11 |
| R 1 ½ | 47.81 | 44.85 | 2.31 | 11 | (R 4 ½) | 125.74 | 122.78 | 2.31 | 11 |
| R 1 ¾ | 53.75 | 50.79 | 2.31 | 11 | R 5 | 138.44 | 135.48 | 2.31 | 11 |

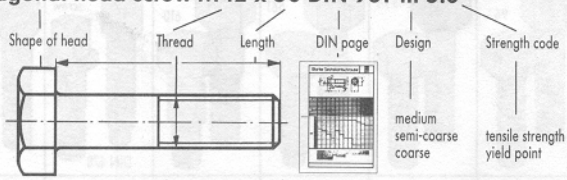
# Screws

**Designation – Strength properties – Design**

DIN 267
(Oct. 67, May 68, April 68)

## Hexagonal head screw M 12 x 50 DIN 931-m 5.6

Example:
Hexagonal head screws
M 12, 50 mm long,
DIN 931, Design m
(refer below)
of steel with the
physical properties 5.6
(refer below)

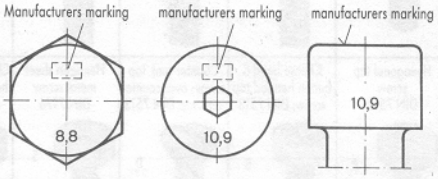



### Strength classes for screws

| Codes for strength classes | | tensile strength $\sigma_B$ | yield point $\delta_S$ | strain $\delta_5$ |
|---|---|---|---|---|
| old | new[1] | N/mm² | N/mm² | % |
| 4 A | 3.6 | 290 | 195 | 25 |
| 4 D | 4.6 | 390 | 235 | 25 |
| 4 S | 4.8 | 390 | 315 | 14 |
| 5 D | 5.6 | 490 | 295 | 20 |
| 5 S | 5.8 | 490 | 390 | 10 |
| 6 D | 6.6 | 590 | 355 | 16 |
| 6 S | 6.8 | 590 | 470 | 8 |
| 6 G | 6.9 | 590 | 530 | 12 |
| 8 G | 8.8 | 780 | 630 | 12 |
| 10 K | 10.9 | 980 | 885 | 9 |
| 12 K | 12.9 | 1180 | 1060 | 8 |
| – | 14.9 | 1370 | 1235 | 7 |

### Coding of the strength classes

Hexagonal and innner hexagonal screws from 5 mm Ø onward with strength class from 6.6 onward.
Set screws from 5 mm Ø onward with strength class from 8.8 onward must be marked with the strength class and manufacturer's symbol




If there is a shortage of space, the following emblems can be used instead of the markings

| Strength class | 5.6 | 8.8 | 10.9 | 12.9 | 14.9 |
|---|---|---|---|---|---|
| Emblem | | | | | |
| Colour stickers used for packing the screws | upto 5.6 green recomm. | red | blue | brown | yellow |

[1] The first number gives 1/100 of the minimum tensile strength in N/mm²
The second number gives 10 times the ratio of the apparant yield point to the minimum tensile strength (yield stress ratio).
Both numbers can be multiplied to give 1/10 of the minimum yield point in N/mm².

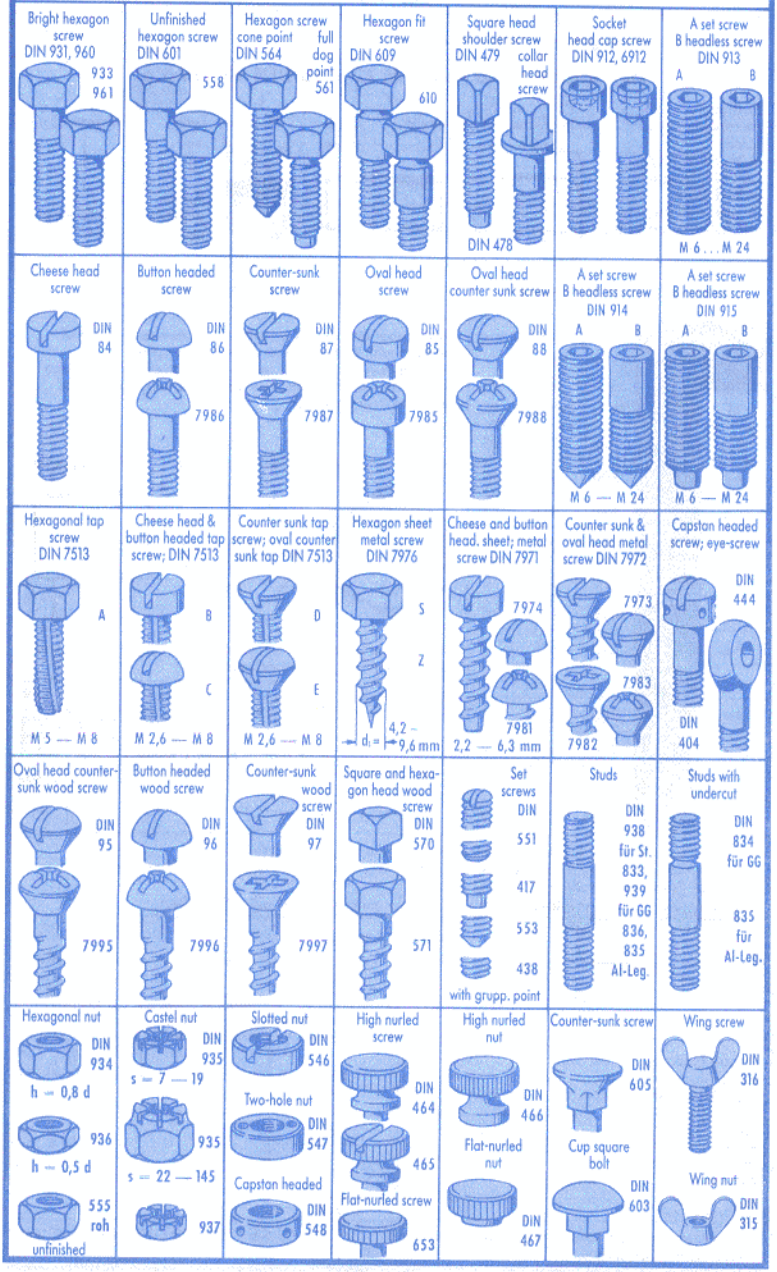
### Design m mg g

| Surface | m medium | mg (semi-coarse) | g (coarse) |
|---|---|---|---|
| | Surface roughness $R_t$ in $\mu$m (max.) | | |
| Thread flanks for screws and nuts.<br>Thread core for screws<br>Supporting surface shank | 25[1] | 25[1] | 40 |
| Heads and flats | 100 | any | any |
| Thread root for nuts<br>Thread outer diameter for screws | any | | |
| Other surfaces | 25 | | |

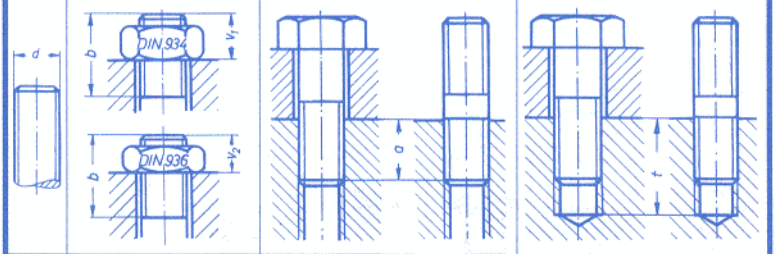
Screws with the left hand thread from onward M 5 must be marked with an L.

[1] for cut thread above M 5: 40 $\mu$m

# Screws nomenclatures



## Threaded length, Inserted end, Depth of threaded hole



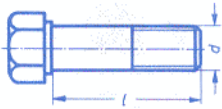

| Threads | Threaded length $b$ | | | Inserted end $a$ for | | | | Depth of thread $t$ for | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Projected end of screw | | Steel bronze | Grey cast iron | Soft metals | Alumi-nium | Steel bronze | Grey cast iron | Soft metals | Alumi-nium |
| | | DIN 78 (Aug. 53) | | DIN 938 (Mar. 53) | DIN 939 (Nov. 53) | DIN 940 (Dec. 55) | DIN 835 (Mar. 53) | DIN 938 (Mar. 53) | DIN 939 (Nov. 53) | DIN 940 (Feb. 54) | DIN 835 Mar. 53) |
| | | | | ≈ 1 · $d$ | ≈ 1.25 · $d$ | ≈ 2.5 · $d$ | ≈ 2 · $d$ | | | | |
| $d$ | $b$ | $v_1$ | $v_2$ | $a$ | $a$ | $a$ | $a$ | $t$ | $t$ | $t$ | $t$ |
| M 3 | 9 | 3.2 | – | 3 | 4 | 8 | 6 | 6 | 7 | | 9 |
| M 4 | 10 | 4.2 | – | 4 | 5 | 10 | 8 | 7.5 | 8 | | 12 |
| M 5 | 12 | 5.2 | – | 5 | 6.5 | 13 | 10 | 9 | 10 | 16 | 15 |
| M 6 | 15 | 6.5 | – | 6 | 7.5 | 15 | 12 | 10.5 | 12 | 19 | 18 |
| M 8 | 18 | 8.5 | 7 | 8 | 10 | 20 | 16 | 13 | 15 | 25 | 24 |
| M 10 | 20 | 10 | 8 | 10 | 12 | 25 | 20 | 15 | 19 | 32 | 28 |
| M 12 | 22 | 12 | 9.5 | 12 | 15 | 32 | 24 | 18 | 25 | 40 | 32 |
| M 14 | 25 | 14 | 11 | 14 | 18 | 35 | 28 | 20 | 28 | 42 | 38 |
| M 16 | 28 | 16 | 11 | 16 | 20 | 40 | 32 | 22 | 30 | 50 | 40 |
| M 18 | 30 | 19 | 13 | 18 | 22 | 45 | 36 | 27 | 32 | 55 | 45 |
| M 20 | 32 | 20 | 13 | 20 | 25 | 50 | 40 | 28 | 35 | 60 | 50 |
| M 22 | 35 | 21 | 14 | 22 | 28 | 55 | 44 | 30 | 38 | 65 | 54 |
| M 24 | 38 | 22.5 | 14.5 | 24 | 30 | 60 | 48 | 32 | 42 | 70 | 58 |
| M 27 | 40 | 24.5 | 16.5 | 25 | 35 | 65 | 55 | 33 | 45 | 75 | 65 |
| M 30 | 45 | 27 | 17 | 30 | 38 | 75 | 60 | 38 | 50 | 88 | 70 |
| M 33 | 50 | 30 | 19 | 32 | 42 | 80 | 65 | 40 | 55 | 92 | 75 |
| M 36 | 55 | 34 | 20 | 35 | 45 | 90 | 70 | 45 | 60 | 105 | 82 |
| M 39 | 60 | 36 | 22 | 38 | 50 | 95 | 78 | 50 | 65 | 110 | 92 |
| M 42 | 65 | 39 | 23 | 42 | 52 | 105 | 85 | 52 | 70 | 120 | 100 |

### Hexagonal screws – Tap screws

Designation-shape and designs with additional order data

DIN 962 (Mar. 53)

For hexagonal screws according to DIN 931, 933, 960 and 961 and for tape screws according to DIN 833, 834, 835, 836, 938 & 939



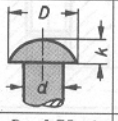
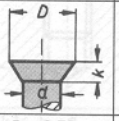
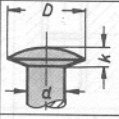
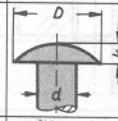
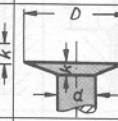
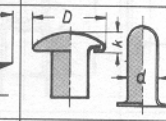

Designation of a hexagonal screw with thread $d$ = M 12 having a length of $l$ = 50 mm shank Ø = thread Ø with taper or oval head, design m or mg, as selected by the manufacturer strength property 4.6 (as per DIN 267)

Hexagonal screw M 12 x 50 DIN 931.4.6

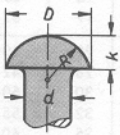
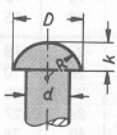
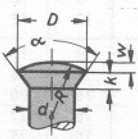
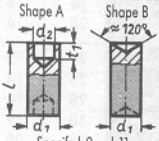
| Form | Diagram | Examples of designation |
|---|---|---|
| **B** Shank Ø Flank Ø | | Hexagonal screw BM 12 x 50 DIN 931 m 4.6 |
| **K** With tapered head | | Hexagonal screw BM 12 x 50 K DIN 931-4.6 |
| **L** With oval head | | Hexagonal screw M 12 x 50 L DIN 931-4.6 |
| **S** With pin hole | | Stud M 12 x 50 S DIN 835-4.6 |
| **SK** With locking hole on head | | Hexagonal screw M 12 x 50 SK DIN 931-4.6 |
| **Sz** With slots | | Hexagonal screw M 12 x 50 Sz DIN 931-4.6 |
| **To** Without plate fitting | | Hexagonal screw M 12 x 50 To DIN 931-4.6 |

# Rivets and pins

## Rivets under 10 mm (designed for sheet riveting)

| Round head rivets DIN 660 (Jun. 56) | Counter-sunk rivet DIN 661 (Jun. 56) | Oval-head rivet DIN 662 (Jun. 56) | Truss head rivet DIN 674 (Dec. 53) | Belt rivet DIN 675 (Jun. 49) | Tubular rivet DIN 7331 (Jun. 53) |
|---|---|---|---|---|---|
| MU St 34<br>Cu Ms Al<br>Al-alloy | MU St 34<br>Cu Ms Al<br>Al-alloy | MU St 34<br>Cu Ms Al<br>Al-alloy | MU St 34<br>Cu Ms Al | Al Cu | St VII 23 |
|  |  |  |  |  |  |
| $D \approx 1.75 \cdot d$<br>$k \approx 0.6 \cdot d$ | $D \approx 1.75 \cdot d$<br>$k \approx 0.5 \cdot d$ | $D \approx 2 \cdot d$<br>$k \approx 0.5 \cdot d$ | $D \approx 2.3 \cdot d$<br>$k \approx 0.5 \cdot d$ | $D \approx 2.8 \cdot d$<br>$k \approx 0.3 \cdot d$ | $D \approx 2 \cdot d$<br>$k \approx 0.4 \cdot d$ |
| $d$ = 1 1.4 1.7 2 2.6 3 3.5 4 5 6 7 8 9 | | $d$ = 1.7 2 2.6 3 3.5 4.5 6 7 8 | $d$ = 1 1.4 2 2.6 3 3.5 4 5 6 7 8 | $d$ = 3 3.5 4 5 | $d$ = 3 4 5 6 |

## Rivet 10 ... 36 mm (steel and boiler construction)

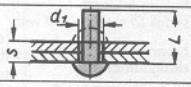
| Undriven Rivet Ø | Round head rivets for boiler construction DIN 123 (Jun. 56) MU St 34 | Round head rivets for steel construction DIN 124 (Jun. 56) MU St 34 | Counter-sunk rivets DIN 302 (Jun. 56) MU St 34 | Pin DIN 7341 (May 53) St 50, Ms 58, Al Mg 3 |
|---|---|---|---|---|
| |  |  |  | Shape A Shape B<br>  <br>Specify h9 or h11 |

| $d$ | $D$ | $k$ | $R$ | $D$ | $k$ | $R$ | $D$ | $k$ | $w$ | $R$ | $\alpha$ | Nominal Ø $d_1$ | $d_2$ | $t_1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 18 | 7 | 9.5 | 16 | 6.5 | 8 | 14.5 | 3 | 1 | 27 | 75° | 2 | – | – |
| 12 | 22 | 9 | 11 | 19 | 7.5 | 9.5 | 18 | 4 | 1 | 41 | | 2.5 | – | – |
| 14 | 25 | 10 | 13 | 22 | 9 | 11 | 21,5 | 5 | 1 | 58 | | 3 | 2 | 1.5 |
| 16 | 28 | 11.5 | 14.5 | 25 | 10 | 13 | 26 | 6.5 | 1 | 85 | | 4 | 2.5 | 2 |
| 18 | 32 | 13 | 16.5 | 28 | 11.5 | 14.5 | 30 | 8 | 1 | 113 | | 5 | 3.5 | 2.5 |
| 20 | 36 | 14 | 18.5 | 32 | 13 | 16.5 | 31.5 | 10 | 1 | 124.5 | 60° | 6 | 4.5 | 3 |
| 22 | 40 | 16 | 20.5 | 36 | 14 | 18.5 | 34.5 | 11 | 2 | 75.5 | | 8 | 6.5 | 4 |
| 24 | 43 | 17 | 22 | 40 | 16 | 20.5 | 38 | 12 | 2 | 91 | | 10 | 8 | 5 |
| 27 | 48 | 19 | 24.5 | 43 | 17 | 22 | 42 | 13.5 | 2 | 111 | | 12 | 10 | 6 |
| 30 | 53 | 21 | 27 | 48 | 19 | 24.5 | 42.5 | 15 | 2 | 114 | 45° | (13) | 11 | 6 |
| 33 | 58 | 23 | 30 | 53 | 21 | 27 | 46.5 | 16.5 | 2 | 136 | | 14 | 12 | 7 |
| 36 | 64 | 25 | 33 | 58 | 23 | 30 | 51 | 18 | 2 | 164 | | 16 | 13 | 8 |

Design details of a round head rivet of 16 mm Ø of the undriven rivet and 38 mm length:
**Round rivet 16 x 38 DIN 124** rivet hole Ø for rivets above 10 mm Ø = undriven rivets Ø + 1 mm

### Length of rivet L

Approximate length of rivet $L$ for round closing head*



$s$ = length under heads  $d$ = rivet hole  $L$ = rivet length

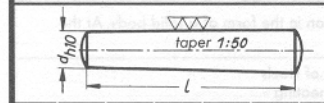
| In steel construction | In boiler construction with length under heads above 54 mm: | In boiler construction with length under heads upto 54 mm: |
|---|---|---|
| $L \approx 1.2 \cdot s + d_1$ | $L \approx 1.5 \cdot s + d_1$ | $L \approx 1.4 \cdot s + d_1$ |

Rivets lengths are calculated with the length under heads and are listed in DIN 124 Pgs. 2. 3. 4.

* Allowance $Z$ for round head ≈ 1.5 Ø, at $d > 20$ mm ≈ 1.7 Ø, for counter-sunk ≈ 0.5 Ø

## Taper pins

DIN 1 (March 61)




Material: St 50 K or 9 S 20 K
The nominal size $d$ is based on the thin end of the pin
Designation: e. g. taper pin 4 x 40 DIN 1

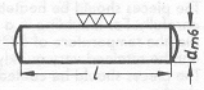
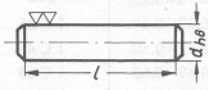
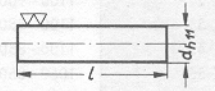
| Ø $d$ | 0.6 | 0.8 | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 12 | 14 | 16 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $l$ | 4... | 6... | 8... | 10... | 12... | 14... | 16... | 20... | 24... | 28... | 32... | 36... | 36... | 40... | 50... |
| | 10 | 14 | 18 | 26 | 36 | 50 | 60 | 70 | 100 | 120 | 140 | 165 | 165 | 230 | 230 |

Standard lengths: 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 36, 40, 45, 50, 55, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 165, 180, 200, 230, 260

## Cylindrical pins

DIN 7 (Jun. 56)

Designation of a cylindrical pin of 4 mm Ø

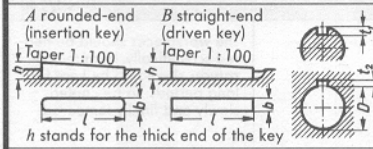
| as a fitting pin | as coupling pin | as rivet pin |
|---|---|---|
|  |  |  |
| Cylindrical pin 4 m 6 x 20 DIN 7 | 4 h 8 x 20 DIN 7 | 4 h 11 x 20 DIN 7 |

| Ø $d$ | 0.8 | 1 | 1.5 | 2 | 2.5 | 3 | 4 | 5 | 6 | 8 | 10 | 12 | 14 | 16 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $l$ | 2... | 3... | 4... | 4... | 4... | 4... | 5... | 5... | 6... | 8... | 10... | 10... | 14... | 16... | 20... |
| | 8 | 12 | 16 | 20 | 24 | 32 | 40 | 50 | 60 | 80 | 100 | 120 | 160 | 180 | 200 |

Standard lengths: 2, 3, 4, 5, 6, 8, 10, 12, 14, 16, 18, 20, 24, 28, 32, 36, 40, 45, 50, 55, 60, 70, 80, 90, 100, 120, 140, 160, 180, 200, Material St 50 K or 9 S 20 K)

## Keys and feathers

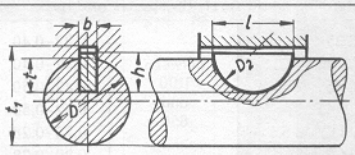
Keys and insertion keys
Tension joint with taper of key
DIN 6886 (Dec. 67)




$h$ stands for the thick end of the key

Designation of key: Form $A$; Breadth $b = 20$ mm height $h = 12$ mm; length $L = 125$ mm;
Material St 60 key $A$ 20 x 12 x 125 DIN 6886

Woodruff keys and keyslots
Driving joint without taper of key
DIN 6888 (Aug. 56)




Designation of a feather key having $b = 4$, $h = 5$
Woodruff key 4 x 5 DIN 6888

| For shafts Ø $D$ | Key width x height $b \cdot h$ | Depth of keyway $t_1$ is measured fr. the apex $t_1$ | Depth of keyway in the hub $t_2$ |
|---|---|---|---|
| 10...12 | 4 x 4 | 2.5 + 0.1 | 1.2 + 0.1 |
| above 12...17 | 5 x 5 | 3 + 0.1 | 1.7 + 0.1 |
| above 17...22 | 6 x 6 | 3.5 + 0.1 | 2.2 + 0.1 |
| above 22...30 | 8 x 7 | 4 + 0.2 | 2.4 + 0.2 |
| above 30...38 | 10 x 8 | 5 + 0.2 | 2.4 + 0.2 |
| above 38...44 | 12 x 8 | 5 + 0.2 | 2.4 + 0.2 |
| above 44...50 | 14 x 9 | 5.5 + 0.2 | 2.9 + 0.2 |
| above 50...58 | 16 x 10 | 6 + 0.2 | 3.4 + 0.2 |
| above 58...65 | 18 x 11 | 7 + 0.2 | 3.4 + 0.2 |
| above 65...75 | 20 x 12 | 7.5 + 0.2 | 3.9 + 0.2 |

| For shafts Ø $D$ | Woodruff key width $b$ | Woodruff key height $h$ | Woodruff key length $l$ | Woodruff key Ø of disc $D_2$ | Depth of keyway in shaft $t$ | Depth of keyway in the hub $t_1$ |
|---|---|---|---|---|---|---|
| 6... 8 | 2 | 2.6 | 6.76 | 7 | 1.8 | $D + 1$ |
| | | 3.7 | 9.66 | 10 | 2.9 | |
| 8...10 | 3 | 3.7 | 9.66 | 10 | 2.5 | $D + 1.4$ |
| | | 5 | 12.65 | 13 | 3.8 | |
| | | 6.5 | 15.72 | 16 | 5.3 | |
| 10...12 | 4 | 5 | 12.65 | 13 | 3.5 | $D + 1.7$ |
| | | 6.5 | 15.72 | 16 | 5.0 | |
| | | 7.5 | 18.57 | 19 | 6.0 | |
| 12...17 | 5 | 6.5 | 15.72 | 16 | 4.5 | $D + 2.2$ |
| | | 7.5 | 18.57 | 19 | 5.5 | |
| | | 9 | 21.63 | 22 | 7.0 | |

# Forming

Forming is the process of finishing through a plastic deformation in the form of a solid body. At the same time the contents of the workpiece are held together.

Temperatures for hot forming of steels
– forging, hot bending, hot heating –

**Plain structural steels** DIN 1700

| Symbol | Highest permiss. temp. in °C | C-content % | Similar to Eurostandard 25 | Observations |
|---|---|---|---|---|
| USt 34-1 | 1330 | 0.17 | Fe 34-A | The steels are not brittle either when cold or red hot. Steels for drop forging bear the letter P. |
| USt 37-1 | 1320 | 0.2 | Fe 37-A | |
| RSt 42-2 | 1300 | 0.23 | Fe 42-B 3 FN | |
| St 50-2 | 1290 | 0.3 | Fe 50-2 | |

**Tempering steel** (high grades steel) DIN 17200

| | | | | |
|---|---|---|---|---|
| C 22 | 1100 – 900 | 0.18 – 0.22 | --- | The pieces should be heated carefully. For moulding in a die, the temperature of 50°C can be attained very quickly. The pieces should be cooled slowly. |
| C 35 | 1100 – 850 | 0.32 – 0.39 | 1 C 35 | |
| C 45 | 1100 – 850 | 0.42 – 0.50 | 1 C 45 | |
| C 55 | 1050 – 850 | 0.42 – 0.60 | 1 C 55 | |
| C 60 | 1050 – 850 | 0.57 – 0.65 | 1 C 60 | |
| Alloyed steel | 1050 – 850 | 0.25 – 0.55 | --- | |

**Hot-rolled tempering steel for springs** DIN 17221

| | | | | |
|---|---|---|---|---|
| 38 Si 7 | 900 – 830 | 0.35 - 0.42 | --- | Heating in neutral or lightly oxidizing furnaces. The highest temperature should not be exceeded. |
| 51 Si 7 | | 0.47 - 0.55 | 50 Si 7 | |
| 60 SiCr 7 | | 0.55 - 0.65 | --- | |
| 55 Cr 3 | 920 – 830 | 0.52 - 0.59 | 55 Cr 3 | |
| 50 CrV 4 | | 0.47 - 0.55 | 50 CrV 4 | |
| 51 CrMo 4 | | 0.48 - 0.56 | 51 CrMo 4 | |

**Heat-resistant steels for screws and nuts** DIN 17240

| | | | | |
|---|---|---|---|---|
| C 35 | between 1100 and 850 | 0.32 - 0.40 | | The workpieces should be heated scientifically. High temperatures should no be kept for long periods. To be cooled slowly and finally tempered. |
| Ck 35 | | 0.32 - 0.40 | | |
| C 45 | | 0.42 - 0.50 | | |
| Ck 45 | | 0.42 - 0.50 | | |
| 24 CrMo 5 | | 0.20 - 0.28 | | |
| 24 CrMoV 55 | | 0.20 - 0.28 | | |
| 21 CrMoV 511 | | 0.17 – 0.25 | | |

**Heat resistant steels for springs** DIN 17225

| Symbol | Forging in °C | Hot bending in °C | C-content in % | Observations |
|---|---|---|---|---|
| 67 SiCr 5 | 1050 – 850 | 900 – 830 | 0.62 – 0,72 | Heat the pieces carefully. Don't maintain higher temperatures for long time. Slowly cool the chrome alloyed steel in ash or sand. |
| 50 CrV 4 | 1100 – 850 | 920 – 830 | 0.47 – 0,55 | |
| 45 CrMoV 67 | 1100 – 850 | 950 – 870 | 0.40 – 0,50 | |
| 30 WCrV 17 9 | 1100 – 850 | 960 – 880 | 0.25 – 0,35 | |
| 65 WMo 34 8 | 1100 – 850 | 980 – 900 | 0.63 – 0,68 | |

**Glow colours for steels** (Temperature in °C)

| 520... | 580... | 650... | 750... | 780... | 800... | 830... | 880... | 1050... | 1150... | 1250...1320 |
|---|---|---|---|---|---|---|---|---|---|---|
| Black brown | Brown red | Dark red | Dark cherry red | Cherry red | Light cherry red | Light red | Yellow red | Dark yellow | Light yellow | White |

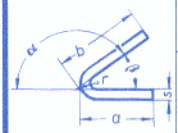
# Cold folding and cold bending

DIN 6935 (May 69)

Smallest permissiable radius of bend $r$ for bend angles $\alpha \leqq 120°$ transverse to direction of rolling.
(for $\alpha > 120°$ the next highest value from the table should be used.
The same applies for folding and bending along the direction of rolling).

| Steel qualities with tensile strength of | for thickness $s$ upto | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 1.5 | 2.5 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 12 | 14 | 16 | 18 | 20 |
| | Radius of bend $r$ | | | | | | | | | | | | | | |
| upto 390 N/mm² | 1 | 1.6 | 2.5 | 3 | 5 | 6 | 8 | 10 | 12 | 16 | 20 | 25 | 28 | 36 | 40 |
| from 390 to 490 N/mm² | 1.2 | 2 | 3 | 4 | 5 | 8 | 10 | 12 | 16 | 20 | 25 | 28 | 32 | 40 | 45 |
| from 490 to 640 N/mm² | 1.6 | 2.5 | 4 | 5 | 6 | 8 | 10 | 12 | 16 | 20 | 25 | 32 | 36 | 45 | 50 |

Stretched length:




$\alpha$ = bend angle
$\beta$ = apex angle
r = radius of bend
s = thickness of sheet
a, b = outer sizes
$f_1$ or $f_2$ = factors for finding the compensating value v

$L = a + b + v$
or $a + b - v$
v = compensating value

$$v = f_1 \cdot r + f_2 \cdot s$$

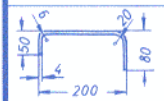
v can be positive or negative depending on the magnitude of angle

calculated compensating value see DIN 6935 additional sheet 2 (May 69)

Values for $f_1$ and $f_2$

| apex angle $\beta$ | bending angle $\alpha$ | $f_1$ | $f_2$ with r : s | | | | |
|---|---|---|---|---|---|---|---|
| | | | > 0.65 | > 1 | > 1.5 | > 2.4 | > 3.8 |
| 0° | 180° | + 1.1416 | − 1.0575 | − 0.9005 | − 0.7433 | − 0.5863 | − 0.4292 |
| 5° | 175° | + 1.0543 | − 1.0838 | − 0.9312 | − 0.7780 | − 0.6207 | − 0.4730 |
| 10° | 170° | + 0.9670 | − 1.1101 | − 0.9618 | − 0.8134 | − 0.6651 | − 0.5168 |
| 15° | 165° | + 0.8798 | − 1.1361 | − 0.9921 | − 0.8481 | − 0.7041 | − 0.5601 |
| 20° | 160° | + 0.7925 | − 1.1622 | − 1.0226 | − 0.8830 | − 0.7433 | − 0.6037 |
| 25° | 155° | + 0.7053 | − 1.1884 | − 1.0532 | − 0.9179 | − 0.7858 | − 0.6474 |
| 30° | 150° | + 0.6180 | − 1.2146 | − 1.0837 | − 0.9527 | − 0.8282 | − 0.6910 |
| 35° | 145° | + 0.5308 | − 1.2408 | − 1.1143 | − 0.9877 | − 0.8644 | − 0.7347 |
| 40° | 140° | + 0.4435 | − 1.2670 | − 1.1448 | − 1.0226 | − 0.9005 | − 0.7783 |
| 45° | 135° | + 0.3562 | − 1.2931 | − 1.1753 | − 1.0575 | − 0.9397 | − 0.8219 |
| 50° | 130° | + 0.2689 | − 1.3193 | − 1.2059 | − 1.0924 | − 0.9790 | − 0.8655 |
| 55° | 125° | + 0.1817 | − 1.3455 | − 1.2365 | − 1.1273 | − 1.0183 | − 0.9092 |
| 60° | 120° | + 0.0944 | − 1.3717 | − 1.2670 | − 1.1622 | − 1.0575 | − 0.9528 |
| 65° | 115° | + 0.0072 | − 1.3981 | − 1.2973 | − 1.1974 | − 1.0971 | − 0.9968 |
| 70° | 110° | − 0.0800 | − 1.4244 | − 1.3285 | − 1.2326 | − 1.1366 | − 1.0407 |
| 75° | 105° | − 0.1674 | − 1.4502 | − 1.3586 | − 1.2670 | − 1.1753 | − 1.0837 |
| 80° | 100° | − 0.2547 | − 1.4764 | − 1.3891 | − 1.3018 | − 1.2146 | − 1.1273 |
| 85° | 95° | − 0.3420 | − 1.5020 | − 1.4197 | − 1.3368 | − 1.2539 | − 1.1710 |
| 90° | 90° | − 0.4292 | − 1.5276 | − 1.4502 | − 1.3717 | − 1.2931 | − 1.2146 |
| 95° | 85° | − 0.3491 | − 1.3876 | − 1.3134 | − 1.2393 | − 1.1651 | − 1.0909 |
| 100° | 80° | − 0.2820 | − 1.2593 | − 1.1895 | − 1.1197 | − 1.0499 | − 0.9801 |
| 105° | 75° | − 0.2256 | − 1.1419 | − 1.0764 | − 1.0110 | − 0.9455 | − 0.8801 |
| 110° | 70° | − 0.1787 | − 1.0339 | − 0.9728 | − 0.9117 | − 0.8506 | − 0.7896 |
| 120° | 60° | − 0.1075 | − 0.8405 | − 0.7882 | − 0.7358 | − 0.6835 | − 0.6311 |
| 130° | 50° | − 0.0599 | − 0.6708 | − 0.6272 | − 0.5836 | − 0.5399 | − 0.4963 |
| 140° | 40° | − 0.0298 | − 0.5185 | − 0.4836 | − 0.4487 | − 0.4138 | − 0.3789 |
| 150° | 30° | − 0.0123 | − 0.3788 | − 0.3526 | − 0.3265 | − 0.3003 | − 0.2741 |
| 160° | 20° | − 0.0036 | − 0.2479 | − 0.2305 | − 0.2130 | − 0.1956 | − 0.1781 |
| 170° | 10° | − 0.0004 | − 0.1226 | − 0.1139 | − 0.1052 | − 0.0964 | − 0.0877 |
| 180° | 0° | 0 | 0 | 0 | 0 | 0 | 0 |

## Examples for calculating the stretched lengths

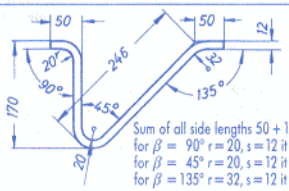



Material: Q St 37.2
$L = a + b + c - v$
$= 50 + 200 + 80 - 22$
$= 308$ mm

$\beta = 90°$, $r = 6$, $s = 4$, $r:s = 1.5$ } $v \approx -8.4$

$\beta = 90°$, $r = 20$, $s = 4$, $r:s = 5$ } $v \approx -13.4 - 8.4$

$v \approx -22$




Material: Q St 37.2 DIN 17100

Sum of all side lengths $50 + 170 + 246 + 50 = 516$
for $\beta = 90°$ $r = 20$, $s = 12$ it gives $v = -25$
for $\beta = 45°$ $r = 20$, $s = 12$ it gives $v = -5.6$
$-6.8 \approx -37$
stretched length $L$ ..... $= 479$

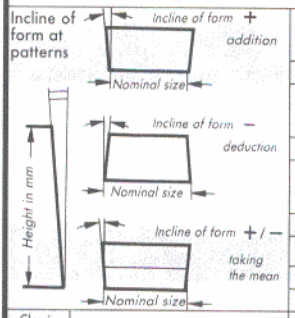
# Moulding

Moulding is the finishing process of a body from formless material obtained from gaseous, liquid or granular state.

## Foundry patterns

DIN 1511 (Oct. 71)

Incline of form at patterns




| Height im mm | upto 10 | from 10 to 18 | from 18 to 30 | from 18 to 50 | from 50 to 80 | from 80 to 100 |
|---|---|---|---|---|---|---|
| Incline | 3° | 2° | 1.5° | 1° | 0.75° | 0.5° |

| Height in mm | from 180 to 250 | from 250 to 315 | from 315 to 400 | from 400 to 500 | from 500 to 630 |
|---|---|---|---|---|---|
| Incline | 1.5 mm | 2.0 mm | 2.5 mm | 3.0 mm | 3.5 mm |

| Height in mm | from 630 to 800 | from 800 to 1000 | from 1000 to 1250 | from 1250 to 1600 | from 1600 to 2000 |
|---|---|---|---|---|---|
| Incline | 4.5 mm | 5.5 mm | 7 mm | 9 mm | 11 mm |

Incline of mould shape for core mark

| Height | upto 70 mm | above 70 mm |
|---|---|---|
| Incline | 5° | 3° |

| Classification of quality | Use | Material | Jointing | Loose parts | Wearing edge |
|---|---|---|---|---|---|
| **H 1a** | Highest accuracy, for series, hand and machine mouldings. 500-1000 moulds. | Hard wood (maple, pear cherry) laminated wood. | Press joint with groove & tongue. Hardwood pins. | Light metal wood. Synthetic resin with metallic device | Metal at least 3 mm thick. |
| **H 1** | High degree of accuracy for a large number of pieces to be hand or machine moulded 200-500 moulds | As in H 1a for large patterns of pine wood | As in H 1a | Synthetic resin, wood with dovetail | Hard wood bandings for large size patterns |
| **H 2** | For hand, moulding small series 30-50 moulds | Alder, pine wood | Rivetted blunt joints, screws | Wood with screws | |
| **H 3** | For single hand mouldings 1-5 moulds | Softwood clamping plate | Cross joints, blunt nails | As in H 2 | Sheets at templates |

Permissible variation of sizes in mm for wooden patterns

| Nomin. size above / upto | | 30 | 30 50 | 50 80 | 80 120 | 120 180 | 180 250 | 250 315 | 315 400 | 400 500 | 500 630 | 630 800 | 800 1000 | 1000 1250 | 1250 1600 | 1600 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H 1a, H 1 | ± | 0.2 | 0.3 | | 0.4 | 0.5 | 0.6 | | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 | 1.3 | 1.5 | 1.8 |
| H 2, H 3 | ± | 0.4 | 0.5 | | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 | 1.2 | 1.4 | 1.6 | 1.8 | 2.1 | 2.5 | 3.0 |

## Metallic patterns

| Classification of quality | Use | Material | Surface | Loose parts | Wearing edges |
|---|---|---|---|---|---|
| **M 1** | Large, series, machine moulding. High expectations on the design | Cast iron, sheet Al-alloy brass | Machining on all the surfaces | Dovetail guide | Minimum 3 mm thickness, steel sheets for Al-alloy |
| **M 2** | Series processing machine moulding | As in M 1 hard lead, pattern metal | Partial & guide surfaces machine finished | As in M 1 | — |

Permissable variation in mm for metal models

| Nomin. size above / upto | | 30 | 30 50 | 50 80 | 80 120 | 120 180 | 180 250 | 250 315 | 315 400 | 400 500 | 500 630 | 630 800 | 800 1000 | 1000 1250 | 1250 1600 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M 1 | ± | 0.1 | 0.15 | | 0.2 | | 0.25 | | 0.3 | | 0.4 | | 0.5 | | 0.6 |
| M 2 | ± | 0.15 | 0.2 | | 0.3 | | 0.35 | 0.4 | 0.45 | | 0.6 | | 0.7 | 0.8 | 1.0 |

# Synthetic material patterns

| Quality grade | Use | Material | Design | Loose parts | Core marking |
|---|---|---|---|---|---|
| K 1 | Serial finishing, machine moulding with high expectations | Synthetic material with shape stability | Made of full material | Dovetail of metal or synthetic material | With compressed grooves or sand ribs |
| K 2 | Medium series machine moulding | Synthetic material | As in K 1 | – | As in K 1 |

Permissible variation in sizes for synthetic material patterns im mm.

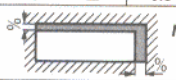
| Nomin. size above | upto | 30 | 30 50 | 50 80 | 80 120 | 120 180 | 180 250 | 250 315 | 315 400 | 400 500 | 500 630 | 630 800 | 800 1000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K 1 | ± | 0.15 | 0.2 | 0.25 | 0.3 | 0.3 | 0.35 | 0.4 | 0.45 | 0.5 | 0.6 | 0.6 | 0.7 |
| K 2 | ± | 0.25 | 0.3 | 0.35 | 0.45 | 0.5 | 0.6 | 0.65 | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 |

## Foam plastic patterns

| Quality grade | Use | Material | Design |
|---|---|---|---|
| S 1 | For patterns, which can be easily removed from the mould; or second cast | Hard foam plastic material, polystyrene with apparant density 20-40 kg/m³ | Coated or smooth surface for light removal from the mould |
| S 3 | Dead mould | Hard foam plastic polystyrene with apparant density below 20 kg/m³ | Made of solid material. Outer surface ground |
| | Dead mould | | As in S 2, low requirements on the surface |

Permissible variation in sizes for foam plastic material in mm

| Nomin. size above | upto | 18 50 | 50 120 | 120 250 | 250 400 | 400 630 | 630 1000 | 1000 1600 | 1600 2500 | 2500 4000 |
|---|---|---|---|---|---|---|---|---|---|---|
| S 1, S 2 | ± | 0.5 | 0.7 | 0.9 | 1.1 | 1.4 | 1.6 | 2.1 | 3.0 | 4.0 |
| S 3 | ± | 0.8 | 1.1 | 1.5 | 1.8 | 2.2 | 2.5 | 3.3 | 4.6 | 6.5 |



**Moulding shrinkage** = difference between the size of the moulds (or of the pattern) and the cast parts soldified in it, in %

| Material | Moulding shrinkage in % |
|---|---|
| Cast iron (lamella graphite) | 1.0 |
| Spher. graphite cast iron (unanneal.) | 1.2 |
| Spher. graphite cast iron (annealed) | 0.5 |
| Cast steel | 2.0 |
| Malleable cast iron GTW | 1.6 |
| Malleable cast iron GTS | 0.5 |
| Aluminium cast alloy | 1.2 |
| Magnesium cast alloy | 1.2 |
| Electrolyte copper cast | 1.9 |
| Cast bronzes (CuSn-alloy) | 1.5 |
| Red bronze (CuSnZn-alloy) | 1.3 |
| Cast brass (CuZn-alloy) | 1.2 |
| Cast special brass (CuZn-alloy) | 2.0 |
| Cast aluminium (CuAl-alloy) | 1.9 |
| Zinc cast alloy | 1.3 |

Colour marks on the patterns — DIN 1511 (Oct. 71)

| Surface or a part of surface in the pattern | Grey cast | Cast steel | Malle-able | Heavy metal | Light cast |
|---|---|---|---|---|---|
| Crude surface, draw edge | red | blue | grey | yellow | green |
| Surface to be finished on cast part | yellow | yellow | yellow | red | yellow |
| | dashes | | | | |
| Place for loose pattern parts to be fitted in | black boundary | | | | |
| Place for chill plates and mandrel marks | blue | red | red | blue | blue |
| Core marks | black | | | | |
| Groove – – – – – – – – | black dash line – – – – – – – – – – | | | | |
| Dead heads etc. Notes on production | Black strips and corresponding letter writing | | | | |
| Methods on the basis of casting techniques | | | | | |
| Insulating laths, stiffner parts on pattern to be insulated | Base colour of the pattern unpainted, but with black stripes | | | | |
| Position of core on part of the surface | black or marked black | | | | |

Experimental values for attaining roughness of surfaces

| Production method | | Surface roughness in µm | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Main group | Term | 16 | 25 | 40 | 63 | 100 | 160 | 250 | 400 | 630 | 1000 |
| Moulds | Sand casting<br>Shell moulding<br>Chill casting | 1) | | | | | | | 2) | | |

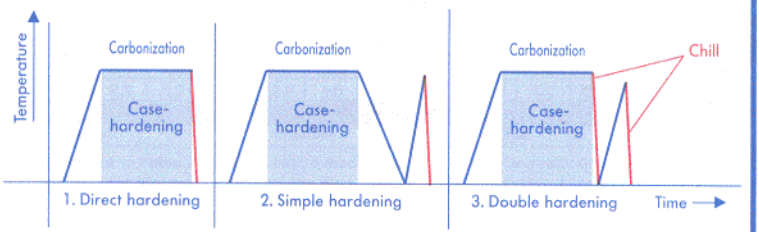
1) Can be obtained only through special methods  2) for specially rough finishing

# Changes in the Properties of Materials

Changes in the properties of materials are due to the process which bring in contact, rearrange or separates the material particles with little change in the form

## Heat treatment of case-hardening steel — DIN 17 210

Case hardening




| Symbol | Case-hardening °C | Cooling from hardened state in (methods see above) | Hardening in °C | Hardening in | Tempering at °C |
|---|---|---|---|---|---|
| C 10, Ck 10<br>C 15, Ck 15<br>Cm 15 | 900 to 950 | 1 a) Water (oil)<br>1 b) Hot quenching (160 – 250 °C) | 880 to 920 | 1) Water (oil)<br>2) Hot quenching (160 – 250 °C) | 150 to 180 |
| 15 Cr 3 | | 2) Case hardening box | 870 to 900 | | |
| 16 MnCr 5<br>20 MnCr 5 | | 1 a) Oil<br>1 b) Hot quenching<br>1 c) Salt bath (580 – 680 °C)<br>2) Case hardening box | 850 to 880 | 1) Oil<br>2) Hot quenching (160 – 250 °C) | 170 to 210 |
| 20 MoCr 4<br>25 MoCr 4 | | 1 a) Oil<br>1 b) Hot quenching (160 – 250 °C) | 890 to 920 | | |
| 15 CrNi 6<br>18 CrNi 8<br>17 CrNiMo 6 | | 1 a) Oil<br>1 b) Hot quenching (160 – 180 °C)<br>1 c) Salt bath (580 – 680 °C)<br>2) Case-hardening box | 840 to 870 | 1) Oil<br>2) Hot quenching (160 – 250 °C) | |

**Soft annealing (G):** As per the cross-section, the parts are annealed for a number of hours at 650 – 700 °C and cooled as slowly as possible

**Heat treatment at tensile strength:** The pieces are cooled at a temperature between 650 – 950 °C and tempered at 500 – 650 °C

## Machining steels — DIN 1651

| | | | | | |
|---|---|---|---|---|---|
| 10 S 20<br>10 SPb 20 | 880 to 950 | 1 a) Water<br>1 b) Hot quenching<br>2) Case-hardening box | 880 to 920 | 1) Water<br>2) Hot quenching | 150 to 150 to 200 |

# Heat treatment of iron and steel

**Technical terms** DIN 17014 (Oct. 59)

| | |
|---|---|
| **Heat treatment** | An operation or combination of operations involving heating and cooling of a workpiece for the purpose of obtaining certain properties. Therefore, the surrounding media may cause changes of the C or N contents in the workpiece processed. Hot-forming or operations of surface protection do not come under the comprehensive term of heat treatment. |
| **Rate of cooling** | Temperature decrease per unit time. |
| **Quenching temperature** | Temperature at which a workpiece is suddenly cooled or quenched. |
| **Tempering** | Subsequent heating after hardening, cold forming or welding operations below the temperature $A_{C1}$ (720° C) followed by preset cooling operation. |
| **Martempering** | Tempering at moderate temperatures in water or oil baths. |
| **Bright annealing** | The method which causes the surface of the workpiece not to oxidize. |
| **Black annealing** | Annealing method by which the surface of the workpiece has a stable oxide layer. |
| **Case hardening** | Hardening after carbonization, possibly accompanied by nitriding operation.<br>Carburizing (applying, cementing)<br>The addition of carbon to the surface of steel at a temperature slightly above the critical level ($A_{C1}$ or $A_{C3}$) in presence of carbonaceous agents: gas-, liquid-, pack- and paste carburizing.<br>Carbo-nitriding. Simultaneous addition of carbon & nitrogen to the surface of the steel part at temperatures slightly above or below the temperature level $A_{C1}$ (720° C) in materials which readily give off carbon and nitrogen.<br>Core hardening. Hardening of carburized and thereafter cooled work piece from hardening the temperature of the core material.<br>Surface hardening. Hardening of the carburized and thereafter cooled workpiece from the hardening temperature of the applied layer.<br>Double hardening. First hardening affects the core portion whereas the second hardening affects the applied layer. |
| **Flame hardening** | Hardening of the workpiece by heating it with the burner flame on the surface or the entire piece uniformly. |
| **Interrupted hardening** | Hardening in two different abrupt working cooling agents (quenching agents) one after the other without stopping in the first cooling agent until temperature equilibrium. |
| **Annealing** | Heating to a definite temperature with subsequent cooling at a low rate. |
| **Full annealing** | Annealing above the upper critical point to obtain a coarse grain structure (e.g. to improve machinability). |
| **Hardening (Quench-hardening)** | Cooling from the temperature above the upper critical point at such a rate that either the surface or the entire steel part gets considerably harder, in the usual way through Martinsite formation. |
| **Hardening temperature** | Temperature of a workpiece to which it is heated prior to the hardening operation. |
| **Induction hardening** | Hardening of workpieces after heating its surface or entire piece through the electrical induction heating. |
| **Nitriding** | Annealing with nitrogen releasing agent for obtaining the nitrogen rich surface. Gas nitriding is done in gaseous phase, batch nitriding in salt baths. |
| **Normalising** | Heating to a temperature just above the upper critical point (with hyper-eutectoid steels above the lower critical point) with subsequent cooling in still air. |
| **Patenting** | Heat treatment of wires and strip. Heating the part above the upper critical point followed by a relatively rapid cooling rate to obtain the desired structure in coldforming operations. |
| **Stress relieving** | Annealing mostly below 650°C with subsequent slow cooling to relieve internal stresses. |
| **Dip-Hardening** | Hardening of the surface of the workpiece by dipping for a short time, into highly heated metal or salt baths. |
| **Super chill** | Secondary treatment for hardened steel upto temperatures of −180° C to minimize the content of residual austenite. |
| **Hardening & tempering** | Heat treatment to achieve greater tenacity at a definite tensile strength by hardening and subsequent annealing, normally at increased temperatures. |
| **Soft annealing** | Annealing at the temperature just below the lower critical point (720°C) or around it with subsequent slow cooling to achieve the softest possible state. |

## Tempering steels

DIN 17200

| Symbol | Soft annealing °C | Normalising °C | Hardening in water °C | Hardening in oil °C | Tempering °C |
|---|---|---|---|---|---|
| C 22, Ck 22<br>C 35, Ck 35<br>C 45, Ck 45<br>C 55, Ck 55<br>C 60, Ck 60 | 650 – 700 | 880 – 910<br>860 – 890<br>840 – 870<br>830 – 860<br>820 – 850 | 860 – 890<br>840 – 870<br>820 – 850<br>805 – 835<br>800 – 830 | 870 – 900<br>850 – 880<br>830 – 860<br>815 – 845<br>810 – 840 | 550<br>to<br>660 |
| 40 Mn 4<br>28 Mn 6 | 650 – 700 | 850 – 880 | 820 – 850 | 830 – 860 | |
| 38 Cr 2<br>46 Cr 2 | 650 – 700 | 850 – 880<br>840 – 870 | 830 – 860<br>820 – 850 | 840 – 870<br>830 – 860 | |
| 34 Cr 4<br>37 Cr 4<br>41 Cr 4 | 680 – 720 | 850 – 890<br>845 – 885<br>840 – 880 | 830 – 860<br>825 – 855<br>820 – 850 | 840 – 870<br>835 – 865<br>830 – 860 | 540<br>to<br>680 |
| 25 CrMo 4<br>42 CrMo 4<br>32 CrMo 12 | 680 – 720 | 860 – 900<br>840 – 880<br>880 – 920 | 840 – 870<br>820 – 850 | 850 – 880<br>830 – 860<br>860 – 900 | 540<br>to<br>680 |
| 36 CrNiMo 4<br>34 CrNiMo 6<br>30 CrNiMo 8 | 650 – 700 | 850 – 880 | 820 – 850 | 830 – 860 | 540<br>to<br>680 |
| 50 CrV 4<br>30 CrMoV 9 | 680 – 720 | 840 – 880<br>860 – 900 | 820 – 850<br>840 – 870 | 830 – 860<br>850 – 880 | 540<br>to<br>680 |

For thick parts, the above temperatures and for thin parts the temperatures given below are applicable.

**Soft annealing (G):** For the above mentioned annealing temperatures the pieces are annealed over a number of hours and are cooled as slowly as possible.

**Normalising (N):** The pieces are heated carefully at the above temperatures and are subsequently cooled in still air.

**Hardening and tempering (V):** As per the cross section, the pieces are heated at the quenching level till the temperature becomes uniform within the piece. The temperature at which the piece is to be kept is chosen according to the desired strength property.

## Glowing colours of steel at higher temperatures

Temperature in °C

520 ... 580 ... 650 ... 750 ... 780 ... 800 ... 830 ... 880 ... 1050 ... 1150 ... 1250...1320

| Black-brown | Brown red | Dark red | Dark cherry red | Cherry red | Light red (cherry) | Light red | Yellowish red | Dark yellow | Light yellow | White |
|---|---|---|---|---|---|---|---|---|---|---|

## Colours of steel at tempering temperatures

Temp. in °C

| 220 | 230 | 240 | 250 | 260 | 270 | 280 | 290 | 310 | 320 | 330 |
|---|---|---|---|---|---|---|---|---|---|---|
| Light yellow | Straw yellow | Dark yellow | Yellowish brown | Brownish red | Purple | Violet | Dark blue | Light blue | Greyish blue | Greyish green |

## Heat treatment of tempering steels

| Symbol | Soft annealing °C | Normalising °C | Hardening in water °C | Hardening in oil °C | Tempering at °C |
|---|---|---|---|---|---|
| **Hot-rolled spring steel** | | | | | DIN 17221 |
| 38 Si 7 | 640 – 680 | 830 – 860 | 830 – 860 | – | 350 – 550 |
| 51 Si 7 | | | 830 – 860 | – | |
| 60 SiCr 7 | | 850 – 880 | – | 830 – 860 | |
| 50 CrV 4 | | | – | | |
| 51 CrMoV 4 | | | – | | |
| **Cold-rolled bands for springs** | | | | | (previous standard) DIN 17222 |
| C 53 | 600 – 650 | | – | 820 – 850 | 390 – 450 |
| C 67 | | | – | 800 – 830 | 420 – 480 |
| C 75 | | | – | 780 – 810 | 420 – 500 |
| M 85 | | | – | 770 – 800 | 440 – 520 |
| 55 Si 7 | 640 – 680 | | – | 830 – 860 | 300 – 360 |
| 65 Si 7 | | | | | |
| 60 SiMn 5 | | | | | |
| Ck 67 | 600 – 650 | | – | 800 – 830 | 350 – 410 |
| MK 75 | | | – | 780 – 810 | 360 – 420 |
| 67 SiCr 5 | 640 – 680 | | – | 830 – 860 | 280 – 340 |
| 50 CrV 4 | | | | | |
| **Heat-resistant steels for springs** | | | | | (previous standard) DIN 17225 |
| 45 CrMoV 6 7 | 740 – 780 | | – | 930 – 960 | 530 – 600 |
| 30 WCrV 17 9 | 740 – 780 | | – | 1050 – 1100 | 600 – 670 |
| 65 WMo 34 8 | 760 – 800 | | – | 1150 – 1200 | 650 – 700 |
| **Heat-resistant steels for screws and nuts** | | | | | DIN 17240 |
| 24 CrMo 5 | | | – | 900 – 950 | 650 – 710 |
| 24 CrMoV 5 5 | | | – | 900 – 950 | 680 – 740 |
| 21 CrMoV 5 1 1 | | | – | 900 – 950 | 680 – 740 |
| **Machining steels** | | | | | DIN 1651 |
| 35 S 20 | | 860 – 890 | 850 – 890 | 850 – 890 | 540 |
| 45 S 20 | | 840 – 870 | 830 – 870 | 830 – 870 | to |
| 60 S 20 | | 820 – 920 | | 800 – 840 | 680 |
| **Nitride steels** | | | | | DIN 17211 |
| | | Nitriding °C | | | |
| 31 CrMo 12 | 650 – 700 | 490 – 510 | – | 870 – 910 | 570 – 700 |
| 39 CrMoV 13 9 | | | – | 920 – 960 | 570 – 650 |
| 34 CrAlMo 5 | | 500 – 520 | 900 – 930 | 910 – 940 | 570 – 650 |
| 41 CrAlMo 7 | | | – | 880 – 920 | 570 – 650 |
| 34 CrAlS 5 | | | 900 – 950 | – | 580 – 660 |
| 34 CrAlNi 7 | | | – | 850 – 900 | 580 – 660 |

## Steels for cutting tools (selection)

AWF 5974 (53)

| Typ | Material Symbol | Composition in % C | Si | Mn | Cr | V | W | Hardening temperature °C | Use |
|---|---|---|---|---|---|---|---|---|---|
| Water hardening | C 55 WS | 0.55 | 0.15 | 0.4 | – | – | – | 780…820 | Knives and frame cutter for leather, paper and soft materials |
| | C 110 W 1 | 1.10 | 0.2 | 0.2 | – | – | – | 750…800 | Small / medium / large: cutting tools with as to hardening technology, simple punches and die plates for a mean number of pieces. |
| | C 100 W 1 | 1.0 | 0.2 | 0.2 | – | – | – | 760…790 | |
| | C 85 W 1 | 0.85 | 0.2 | 0.3 | – | – | – | 770…800 | |
| Oil hardening | 90 Mn V 8 | 0.9 | 0.2 | 2.0 | – | 0.1 | – | 750…850 | Cutting tools, also punching dies with Preferred. by precision mechanics and watch industry: simple punches and die plates for a large number of pieces, also shearing and parting blades |
| | 105 Mn Cr 4 | 1.05 | 0,3 | 1.1 | 0.9 | – | – | 800…830 | |
| | 145 Cr 6 | 1.45 | 0.2 | 0.6 | 1.4 | – | – | 750…850 | |
| | 105 W Cr 6 | 1.05 | 0.2 | 1.0 | 1.0 | – | 1.2 | 750…850 | |
| | 60 W Cr V 7 | 0.55 | 1.0 | 0.3 | 1.0 | 0,2 | 2.0 | 850…900 | Punching die for thickest sheets |
| | 48 Cr Mo V 67 | 0.5 | 0.3 | 0.7 | 1.5 | 0.3 | Mo 0.7 | 850…900 | Cutting tools for all types, particularly for special tough, cutting tools for thickest sheets and large numbers of pieces. Also intermittant and vibrator cutting. |
| Oil- and air harden. | X 210 Cr 12 | 2.1 | 0.3 | 0.3 | 12 | – | – | 930…980 | Heavy duty cutting tools of all types, particularly complicated series and total sections, also scraping and trimming tools for a large number of pieces. |
| | X 210 Cr W 12 | 2.1 | 0.3 | 0.3 | 12 | – | 0.7 | 930…980 | |
| | X 210 Cr Co W 12 | 2.1 | 0.3 | 0.4 | 13 | Mo 0.4 | 0.7 | 960…1000 | As before, also for cutting dynamo and core plates containing silicon; sheets upto 2 mm |

## Steels for punching and drawing tools

AWF 5974 (53)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Water hardening | C 110 W 1 | 1.1 | 0.2 | 0.2 | – | – | – | 750…780 | Bending, rolling, flange and form punching as well as drawing tools for simple forms, for medium pressure and mean numbers of pieces. |
| | C 100 W 1 | 1.0 | 0.2 | 0.2 | – | – | – | 750…780 | |
| | C 85 W S | 0.85 | 0.2 | 0.3 | – | – | – | 770…800 | |
| | 90 Cr 3 | 0.9 | 0.2 | 0.3 | 0.8 | – | – | 770…800 | Pressure and bend punching, drawing dies and forming punches for coins. |
| Oil hardening | 105 Mn Cr 4 | 1.05 | 0.3 | 1.1 | 0.9 | – | – | 800…830 | Bending punches, straight wedge for simple loading / for medium loading / for high loading: punches for cutting tools, embossing tools and striking tools for finishing, piercing punches and bottom tools. |
| | 145 Cr 6 | 1.45 | 0.2 | 0.6 | 1.4 | – | – | 820…850 | |
| | 105 W Cr 6 | 1.05 | 0.2 | 1.0 | 1.0 | – | 1.2 | 820…850 | |
| | 60 W Cr V 7 | 0.55 | 1.0 | 0.3 | 1.0 | 0,2 | 2.0 | 860…890 | Bead and flange rolling, fork punching massive embossing machine, drawing tools and dies, for high pressure and large numbers of pieces. |
| | 48 Cr Mo V6 7 | 0.5 | 0.3 | 0.7 | 1.5 | 0.3 | Mo 0.7 | 850…940 | |
| | X 45 Ni Cr Mo 4 | 0.4 | 0.2 | 0.5 | 1.5 | Ni 4 | 0.5 | 850…940 | |
| Oil- and air harden. | G-X 165 Cr Mo V12 | 1.65 | 0.3 | 0.3 | 12 | Mo 0.6 | 0.5 | 970…1000 | For highly stressed fine bending punches, planishing punches, forming punches for coins, thick-walled drawing dies, extrusion tools with high wear resistance for high pressures and large numbers of pieces. |
| | X 210 Cr 12 | 2.1 | 0.3 | 0.3 | 12 | – | – | 930…960 | |
| | X 210 Cr W 12 | 2.1 | 0.3 | 0.3 | 12 | – | 0.7 | 950…980 | |
| | X 210 Cr Co W 12 | 2.1 | 0.3 | 0.4 | 13 | Mo 0.4 Co 1 | 0.7 | 960…1000 | |

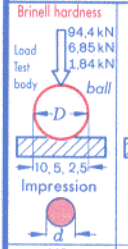
## Steels for hot bending and hot stamping tools

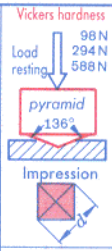
AWF 5974 (53)

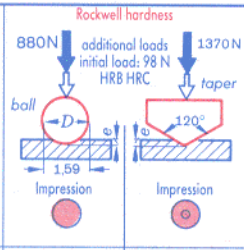
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 56 Ni Cr Mo V 7 | 0.55 | 0.3 | 0.7 | Mo0.5 1.0 | Ni1.7 0.1 | – | L 860…900 O 840…880 Oil | Bending and hot stamping machines for hot bending of parts of 10 mm thickness. The same applies, however, for parts thicker than 10 mm thickness. |
| | X 30 W Cr V 53 | 0.3 | 0.2 | 0.3 | 2.5 | 0.6 | 4.5 | 1050…1100 | |

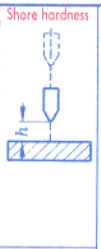
Water hardening: Sensitive to distortion on hardening, glass type hard layer, tough core.
Oil hardening: Less distortion on hardening, hardening through, cannot bear heavy bending stresses.
Air hardening: Very little distortion on hardening, hardening-through, still low bending stresses.

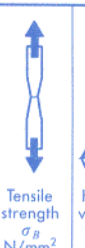
# Hardness comparison



| HB | HV | HRB | HRC | HS | $\sigma_B$ N/mm² | |
|---|---|---|---|---|---|---|
| | 940 | | 68 | 97 | | Glass hardness |
| | 900 | | 67 | 95 | | |
| | 880 | | 66 | 94 | | |
| | 840 | | 65 | 92 | | |
| | 820 | | 64 | 91 | | |
| | 780 | | 63 | 88 | | |
| | 760 | | 62 | 87 | | |
| | 720 | | 60 | 85 | | |
| | 690 | | 59 | 83 | | |
| Use: The Brinell test can only on be carried out on materials having Brinell hardness upto 400 | 670 | | 58 | 81 | | |
| | 650 | | 57 | 80 | | |
| | 630 | | 56 | 78 | | |
| | 610 | | 55 | 77 | | |
| | 590 | | 54 | 75 | | |
| | 570 | | 53 | 73 | | |
| | 560 | | 52 | 72 | | |
| | 530 | | 50 | 70 | | |
| | 480 | | 47 | 65 | | |
| 430 | 450 | | 45 | 62 | 1470 | |
| 408 | 420 | | 42 | 59 | 1390 | |
| 385 | 390 | | 40 | 55 | 1290 | |
| 368 | 370 | | 38 | 52 | 1240 | |
| | 340 | Use: Rockwell tests can only be carried out with steel balls in the range from HRB = 35 to 100 | 35 | 49 | 1150 | |
| | 320 | | 33 | 46 | 1080 | |
| | 300 | | 30 | 43 | 1010 | |
| | 285 | | 28 | 41 | 960 | |
| | 265 | | 25 | 39 | 880 | |
| | 250 | | 23 | 36 | 840 | |
| | 235 | | 20 | 34 | 790 | |
| | 225 | 99 | | 32 | 760 | |
| | 210 | 97 | Use: Rockwell tests with diamond balls only in range of HRC = 20 to 67 | 30 | 710 | |
| | 200 | 95 | | 29 | 680 | |
| | 190 | 93 | | 28 | 640 | |
| | 175 | 90 | | 26 | 590 | |
| | 160 | 85 | | 25 | 540 | |
| | 145 | 80 | | 22 | 490 | |
| | 135 | 76 | | 20 | 460 | |
| | 120 | 70 | | 18 | 410 | |
| | 105 | 60 | | 15 | 360 | |
| | 90 | 47 | | | 310 | |
| | 80 | 36 | | | 270 | |

Use: Vickers tests can be carried out on all materials. For very fine, very hard and very thin workpieces, as well as for additional nitrided steels.

High speed steel
Alloyed steel for tools
Unalloyed steel for tools
Tempered steel
Case hardened steel

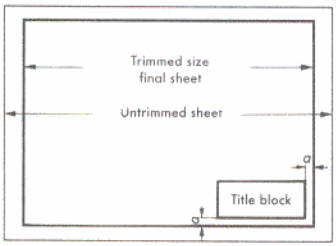
Measurements are made for:

- HB: The diameter of ball impression.
- HV: The diagonal of the pyramid impression.
- HRB: Depth of the cone impression (= hardness number).
- HRC: Depth of the cone impression (= hardness number).
- HS: Rebound height (= hardness number).

# Technical drawing

## Standard sheets sizes and scales

DIN 823 (Aug. 65)




| Standard sheet size | Trimmed size final sheet | Distance $a$ | Untrimmed sheet |
|---|---|---|---|
| A 0 | 841 x 1180 | 10 | 880 x 1230 |
| A 1 | 594 x 841 | 10 | 625 x 880 |
| A 2 | 420 x 594 | 10 | 450 x 625 |
| A 3 | 297 x 420 | 10 | 330 x 450 |
| A 4 | 210 x 297 | 5 | 240 x 330 |
| A 5 | 148 x 210 | 5 | 165 x 240 |
| A 6 | 105 x 148 | 5 | 120 x 165 |

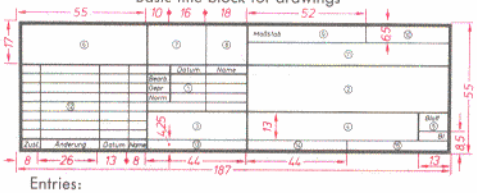
Uncut sheets may be used either vertically or horizontally. For the smaller sizes, the vertical usage of sheets is preferred. For small drawings, a filling margin of upto 25 mm is permissible, so that the usuable area of the final size is reduced. (DIN 820)

Scale: Full size 1:1
Reduced: 1:2.5 1:5 1:10 1:20 1:50 1:100 1:200 1:500 1:1000
Enlarged: 2:1 5:1 10:1
In the title block, the main scale is written in large lettering and the rest of the scales in smaller lettering. The letter is repeated at the pertaining drawings.

## Title block

DIN 6771 Pg. 1 (Dec. 70)

Basic title block for drawings




Line thickness

| | |
|---|---|
| Boundary of the title block | 0.7 mm |
| Boundary of the main field | 0.35 mm |
| All other lines | 0.18 mm |

Note: The dimension of the title block are based on the modular dimension of $a = 4.25$ mm for the height and $b = 2.6$ mm for the width (e.g. field ②: Dimensions $5\,a \times 34\,b$)

Entries:

① Name of the draftsman and the examiner of the drawing with dates

② Nomenclature of the representation (if possible according to the structural shape)

③ Firm of the draftsman of the drawing

④ Drawing number of the draftsman

⑤ Page number and number of pages drawing number (under that note of the page number)

⑥ Possible use, following entries, modifications

⑦ Permissible allowance of free dimensions (e.g. permissible allowance fine DIN 7168)

⑧ Data for quality of surface (e.g. surface series 3 DIN 3141)

⑨ Entry of the drawing scale

⑩ For subsequent entries or weight-data

⑪ For free disposal e.g. working material model number, raw part, semi-finished product

⑫ for modification remarks

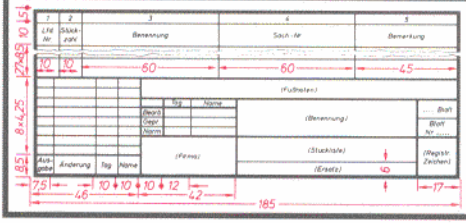
⑬ Original source data if the drawing is originated from some other

⑭ Drawing number, which is not void any more with this drawing

⑮ Drawing number by which this drawing is replaced

## List of parts DIN A 4

DIN 6771 Pg. 2 (Oct. 49)




Note:
List of parts is finished separately from the drawing. The entries follow the serial. No. from above to below (only with a modification in the title block from below to above).

## Lines

DIN 15 (Dec. 67)

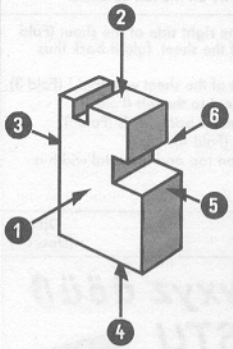
| Types of lines | Line group 0,25 \| 0,35 \| 0,5 \| 0,7 \| 1,0 \| 1,4 — Line thickness in mm | Application |
|---|---|---|
| Full lines | 0,25 \| 0,35 \| 0,5 \| 0,7 \| 1 \| 1,4 | Visible edges of parts, contours, welding seams, welding lines. Thread limiting lines according to JSO. |
| | 0,13 \| 0,18 \| 0,25 \| 0,35 \| 0,5 \| 0,7 | Thread lines according to JSO, dimension and extension lines, cross sections e.g. arm cross section, reference lines, surface area drawings, contour lines of adjacent parts, diagonal cross, bending edges. |
| Dash line | 0,18 \| 0,25 \| 0,35 \| 0,5 \| 0,7 \| 1,0 | Invisible edges, (also threads according to JSO) whereby transparent parts can be treated like opaque ones. Thread lines (used earlier) dendendums, racks and worm gears. |
| | 0,25 \| 0,35 \| 0,5 \| 0,7 \| 1 \| 1,4 | Intersection lines (dashes shorter than with centre lines.) coding of surface treatment or heat treatment. |
| Dash dot lines | 0,13 \| 0,18 \| 0,25 \| 0,35 \| 0,5 \| 0,7 | Centre lines, ores pitch circle, with hole finished parts, drawing of unfinished parts, machining allowance maximum, drawing of the original form (e.g. extended lines). Marking of the boundary lines with individual units. |
| Freehand lines | 0,13 \| 0,18 \| 0,25 \| 0,35 \| 0,5 \| 0,7 | Interruption lines for metals, insulating materials, stones etc. Interruption lines for wood (zig-zag-lines), wood cross-sect. |

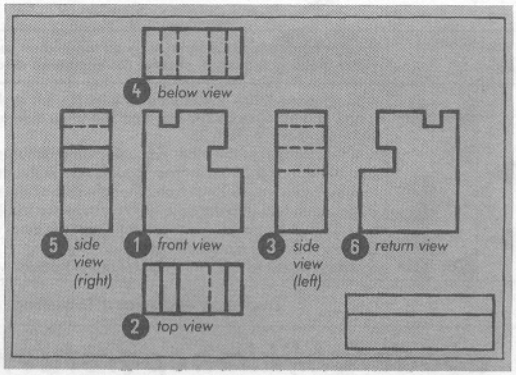
Within a sketched representation only lines of one group should be used.

## Views

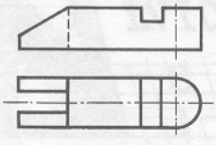
DIN 6 (Mar. 68)

**Direction of viewing 1 ... 6 gives the following**

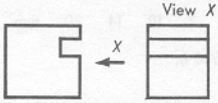



The front view shows the work piece in its operational position and so that possibly much of the shape and dimensions should be visible.



Only those views will be represented which are neccessary to get an idea of the shape and dimensions of a workpiece. If it is not possible to give a clear description of the piece in the standard way, (i.e. front view, top view, side view etc.) then sectional representations are to be used. Showing the hidden edges should be avoided.



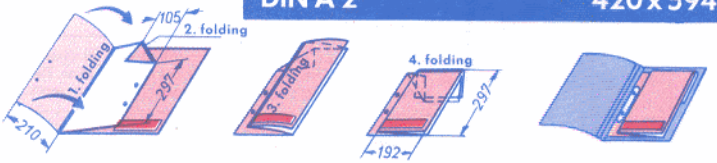

If the usual method has not been followed, the direction of the view must be shown by a letter and arrow. (Arrow and letter should be bigger than the arrow showing the dimensions and the dimension figures respectively. "View X" should be marked above the representation. Both the views can be made anywhere on the drawing sheet.

Folding of Drawings DIN A 4

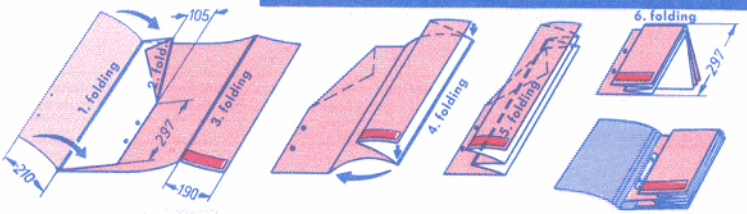
DIN 824 (Jan. 56)

## DIN A 3 — 297 x 420

## DIN A 2 — 420 x 594




## DIN A 1 — 594 x 841




| Folding DIN A3 | A2 | A1 | The title block after folding must be on top and on such places from where it is visible. Folding sequence, observe the numbered arrows on the left columns. |
|---|---|---|---|
| | 1 | 1 | With template (210 x 297) fold over from the left to the right side of the sheet (Fold 1) and at a distance of 297 mm from the lower side of the sheet, fold it back thus making a triangle (Fold 2). |
| | 2 | | Turn the drawing to the other side, cover the right side of the sheet with fold 1 (Fold 3) |
| 1 | | | Fold a distance of 190 mm from the left side of the sheet to the left (Fold 1) |
| | | 2 | Fold a distance of 190 mm from the right side of the sheet backwards (Fold 3) |
| | | 3 | Once again fold at a distance of 190 mm to the front (Fold 4). |
| 2 | | 4 | Fold the rest in such a way that the title block comes on top and the total width is 210 mm (A 3 = Fold 2, A 1 = Fold 5). |
| | 3 | 5 | Fold to a height of 297 (A 2 = Fold 4, A 1 = Fold 6). |

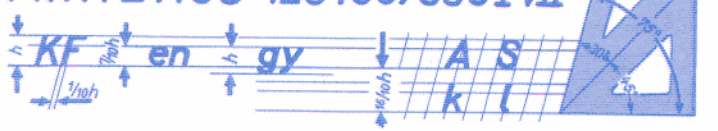
## Inclined standard lettering

DIN 16 (Dec. 67)

abcdefghijklmnopqrstuvwxyz äöüß

ABCDEFGHIJKLMNOPQRSTU

VWXYZÄÖÜ 1234567890IVII




Inclination of letters = 75° Lettering size = 1.8 2.5 3.5 5 7 10 14 20 mm

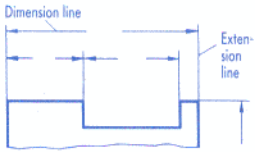
If *h* is height of the capital letter:

the height of the lower case letters = 7/10 *h*,
the line width = 1/10 *h*,
the line to line distance = 16/10 *h*.

# Dimension lines, arrows and dimensions

DIN 406 (June 68)

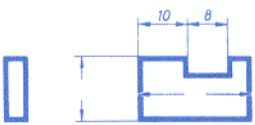
The determining factors for the entry of dimensions are the production, function & testing of the parts.



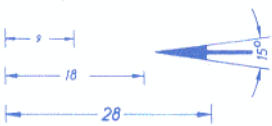

Each dimension should be shown only once. The dimension on visible edges are to be stated clearly.
Use of hidden edges should be avoided.
Dimension lines are thin and at the end, they have an arrows, point in case less space. As far as possible the dimension lines and extension lines should not intersect each other.

Dimension lines are interrupted in the middle by the gaps for dimension figures. Dimension lines are drawn outwards, or from the outer side to the extension lines, if the place for dimension figure is insufficient. They can be shortened either for long symmetrical parts or for many diameter values.

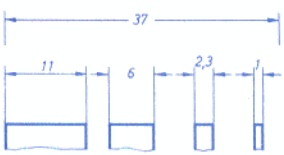
Extension lines are drawn 1-2 mm extra over the dimension line and are vertical to the edge of the object. (As an exception upto 60°) and as far as possible they should not intersect other lines.
Centre lines can also serve as extension lines, and on from the outer edge of the object can be sketched as continuous line.




Extension lines and centre lines should not be drawn from one view to another.
In the case of particularly thick edges, they are drawn for outer dimensions from outer edges while inner dimension lines are drawn from the inner edges of the thick lines.

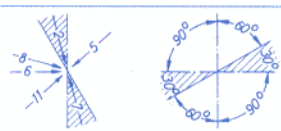



Dimension arrows are pointed ( ≈ 15°), thin (length ≈ height of numbers ≈ 5 times the line thickness of the edges), full and dark black.
They should not touch the corner of the drawing. Dimension lines representing the radius and shortened diameters have only one arrow.



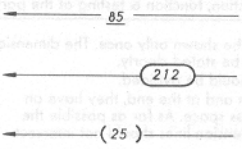

Dimension figures are dark black and are put in the broken dimension lines, for continuous drawn dimension lines above the dimension lines, for inward drawn dimension lines in between the dimension arrows, above or quite close to the dimension lines. Dimensions should not be less than 3,5 mm and must be of the same size. Additions like spheres, minimum size and others should be written somewhat smaller but not less than 2,5 mm.

Dimension figures should not be intersected by lines (centre lines) and on edges of lines or lie at intersection points of lines. With several dimensions, they can be placed a left or right alternately or near the centre line.



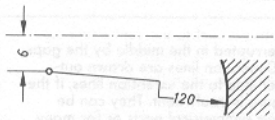

Dimension figures and angles data should be legible from below or from the right. Dimension lines under an angle of 0.....30° to the vertical line are to be avoided. If they must be shown at this position, they should be legible from the left.

## Radius Diameter Square Symbol Sphere



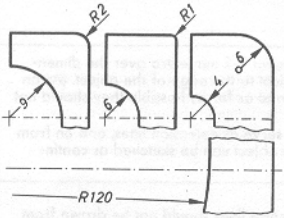

Not to scale entered dimensions must be underlines (not for parts drawn with broken lines).

Encircled dimensions (212) indicates that it will be checked by the ordering party. Bracketed figure (25) indicates that the dimension should not be necessarily modified but it may be useful for the measurements.

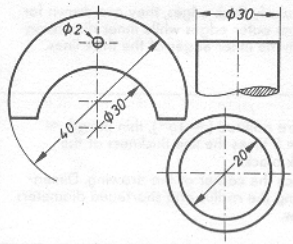



Radii have only one arrow head on the arc of the circle. The centre point is shown by a cross, a small circle or point.

If in case of large radii they are to be provided with dimension, the radius with small rigth-angled bend should be used to represent.




Radius "R" is used if the centre point has not been marked. This could be the case for small radii due to space shortage. For large radii R is used if the centre point lies outside the drawing, or at a different view, or if it is not visible due to the diagram.

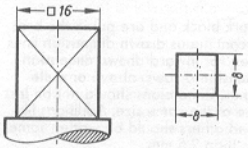



Diameter symbol "Ø" is written before and at the same height as the dimension figure and is placed where:

1. The circle appears as straight line.
2. The diameter dimension has only one arrow.
3. The dimension figure is placed on a circle without using the dimension line, but with the reference line.

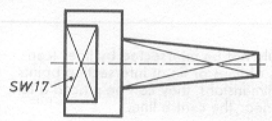
The symbol of diameter is to be left out, when diameter with two arrows in or on the circle appears.

The total height of Ø is equal to the dimension figures. 75° angled line; circle diameter = height of small letters.



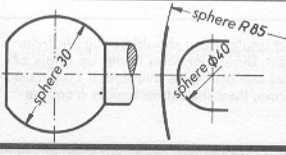

Square Symbol "□" must be placed at the same height as the dimension figure and only where the square is depicted as a straight line.

Square symbol should be of the same size as a small letter. If the square is seen in a section, it would be advisable to write dimensions on two sides.

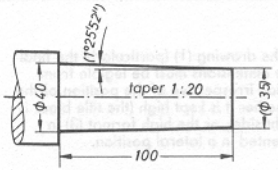



Diagonal cross (thin) represents four sides surfaces. If the top or side views are missing, diagonal crossed lines should be used.

The diagonal cross is also permissible with two views.



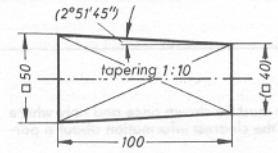

Sphere is placed in front of the dimension figure. If the spherical form is not complete and its centre point not visible, or if the dimension lines are shown only with an arrow head, then the Ø symbol or the R symbol is put between the sphere and the dimension figure. In the case of screw ends, the symbol "sphere R" is left out.



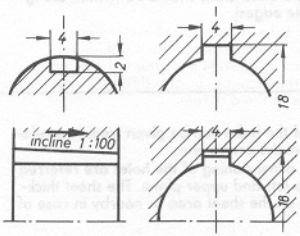

Tapers have the data parallel to the centre line e.g.:
Taper 1:20 $1:x=(D-d):l$
in example: $1:x=(40-35):100=1:20$

Semi taper angle $\frac{\alpha}{2}$ is to be shown additionally in brackets.

$\frac{\alpha}{2}$ is determined from $\tan\frac{\alpha}{2}=\frac{D-d}{2\cdot l}$

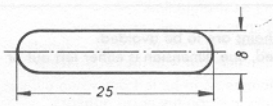



Pyramids have the data parallel to the centre line e.g.
Tapering 1:10 $1:x=(a-b):l$
or parallel to the inclined line it has the data e.g.
inclination 1:20 $1:x=(a-b):2l$

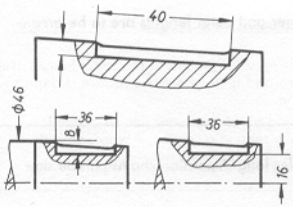



Keyways for feather and taper keys. In many cases it suffices for shafts to give the depth of the keyways, for holes – the sum of the diameter + depth of the keyways.

The drive direction for taper keys is shown by an arrow.

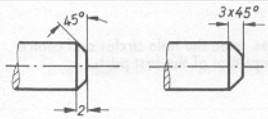



Long holes (also keyways) require the dimension of length and width in the top view.



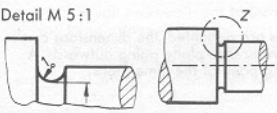

Grooves in tapers

The base line of the groove is parallel to the inclined surface line of the taper.
The base line is parallel to the axis of the taper. One needs to show the dimension only of the surface of the cylinder which comes closest to the centre line or else one can show it by starting from the centre line and going outwards. If there is a shortage of space, the diameter dimensions can be shown outside.




Dimensioning chamfers

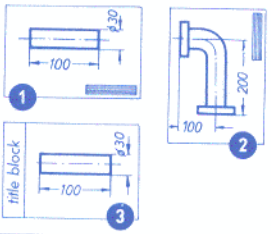
The simplified dimensioning is permitted only for chamfers of 45°. It could also be used in the case of counter sinking of 90° (Chamfer 45°).



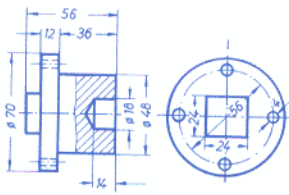

Details can be shown on enlarged scale. The scale must always be given.

A circle (with a thin dash and dotted line) with a capital letter indicates the location.

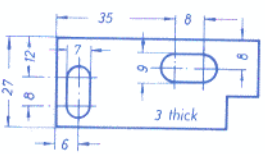
## Arranging the dimension — Hole pitches



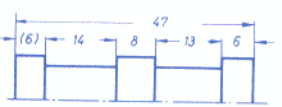

In the usual practice the drawing (1) (particularly the final state of the parts), the dimensions must be legible from below and the right side irrespective of the position of the lateral format (2). Whether it is kept high (the title block is then on the upper right side), or the high format (3) in which the part is presented in a lateral position.



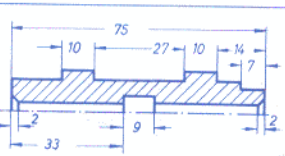

Each dimension figure must be shown once and only where it is necessary to give the clearest information about a particular part.
As far as possible the dimensions should be written along the solid lines (visible edges).



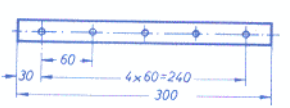

The dimensioning of the holes can be given from two reference planes or from the centre line.
In the example, the dimensioning of the holes are referred to the planes on the left and upper plane. The sheet thickness can be written on the sheet area or nearby in case of space shortage.




Enclosed dimension chains are to be avoided.
If it can not be avoided, one dimension is either left out or put into brackets.

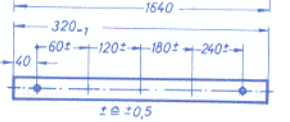



Dimensions of the inner and outer lenghts are to be arranged separately.



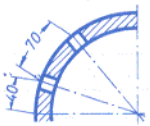

With equi-distant holes long dimension chains can be simplified.

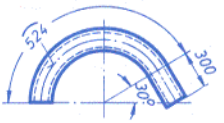
With many similar pitches, even the hole circles and centre lines can be left out except that of the first pitch.



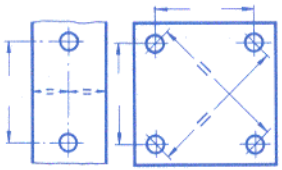

If only small allowances are permitted, the dimensions can be arranged from the reference plane going outwards. A dot indicates the starting point of the dimensions.

## Dimensioning of curves



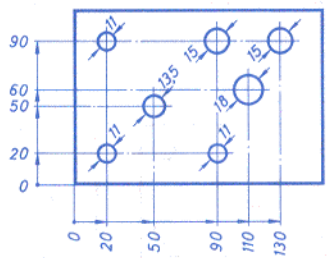




Curve dimensions. For curves having an angle of 90° or less, the extension lines for the dimensions are drawn parallel to the line bisecting the angle and the line is shown as an arc. For arcs with an angle of greater than 90° dimension lines are indicated by using the centre of the bend as a base and a small arc is drawn above the dimension figure (often the case with bent pipes). if required the dimension can be shown with an indicating line to the arc.



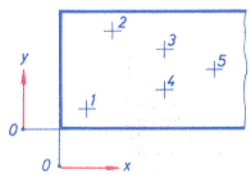
Equality mark
To ensure the centricity in the case of roughly tolerated widths; the equality mark can be used. The same would be the case if hole distances are roughly set or if the holes should fit in the bends.

## Dimensioning by coordinates




To work on boring machines-particularly on numerically controlled ones dimensioning by coordinates is beneficial.

The holes do not always have to be indicated with a circle. It is enough to show their position with a cross.




| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| x | 20 | 25 | 50 | 50 | 75 |
| y | 20 | 65 | 55 | 25 | 40 |
| ⌀ | 11 | 155 | 13 | 13 | 18 |

**Permissible deviations for dimensions without tolerance data** DIN 7168 (Aug. 70)
(Free dimension tolerances for machining operation)

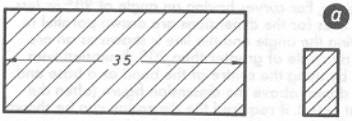
| Degree of accuray | | Length measures permissible allowance (mm) Range of nominal size (mm) above | 3 | 6 | 30 | 120 | 315 | 1000 | Angle per. allowance (degr. & minute) Range of nominal size (mm) Length of the short side | 10 | 50 | 120 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | upto | 6 | 30 | 120 | 315 | 1000 | 2000 | 10 | 50 | 120 | |
| fine | ± | | 0.05 | 0.1 | 0.15 | 0.2 | 0.3 | 0.5 | 1° | 30' | 20' | 10' |
| medium | ± | | 0.1 | 0.2 | 0.3 | 0.5 | 0.8 | 1.2 | | | | |
| coarse | ± | | 0.2 | 0.5 | 0.8 | 1.2 | 2.0 | 3.0 | 1°30' | 50' | 25' | 15' |
| very coarse | ± | | 0.5 | 1 | 1.5 | 2 | 3 | 4 | 3° | 2° | 1° | 30° |

Instructions as per DIN 7168 are to be given in title block or nearby. e.g. "Dimensions without tolerance data according to DIN 7168 (m)".

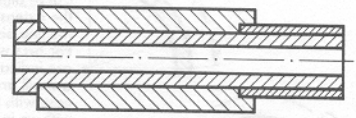
# Sections

Extract DIN 6 (Mar. 68)

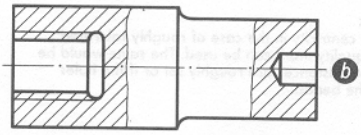
A section is the thought separation of the object through one or more planes. As per the periphery and the position the differentiation is done such as: Full section ⓐ, Local section ⓑ, Half section ⓒ



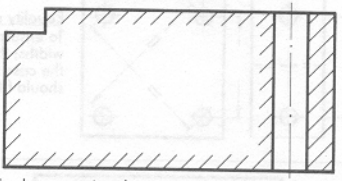

Selectional areas have thin lines at an inclination of 45° to the axis. The distance of the shaded lines from one another are to be adjusted to the size of surface areas shown. The section lines are interrupted to insert the dimension figures and letters.



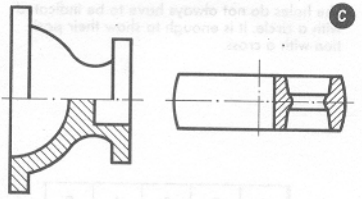
Adjoining sectional areas for different parts are hatched in different ways. Different directions and distances between the hatched lines are used for different sections. The section position is arbitrary: preferred direction within the longitudinal axis or perpendicular to it.



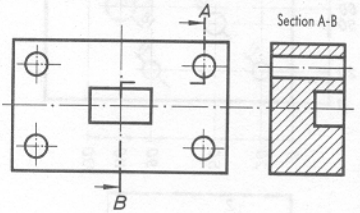

All sectional areas of the same parts are hatched alike. A local section or break is drawn by free-hand.



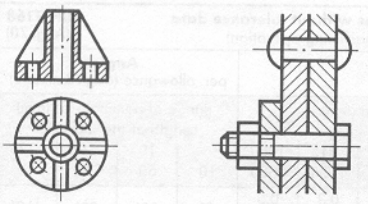
For large sectional areas, one needs only to hatch the marginal zone following the contour of the sectional area.



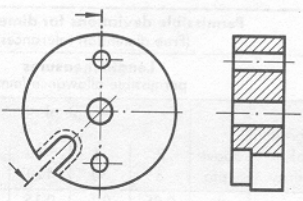

Symmetrical parts can be drawn in one half section (i.e. showing half the section clearly). The lower half of the section is shown with a horizontal centre line, with vertical centre lines the right part is drawn.




If the location of the sectional plane is not very clear, it is shown with thick dash/dot lines according to DIN 15. The direction of view is marked by an arrow. If letters are marked on the sectional line, the letters are to be repeated above the cross-section, e.g. Section A-B. Arrow: 1.5 x arrow head size in the dimension line.



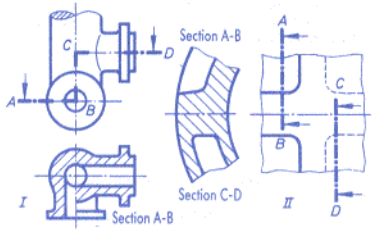
If rivets, spokes, shafts, bolts, screws etc. lie in the sectional plane, they are not shown on a longitudinal section. For flanges with bracing ribs and holes or similar parts, no indication on the sectional plane is necessary.



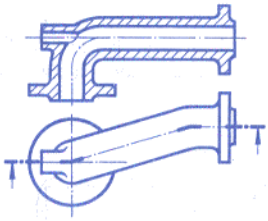
If two planes intersect at an angle the section should be drawn in such a way that the sectional surface is on one plane, i.e. the plane of one section is to be transposed to the plane of the other.

# Sections

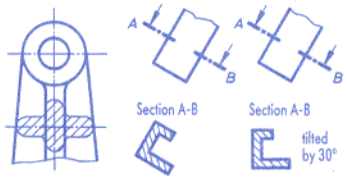
Extract DIN 6 (Mar. 68)



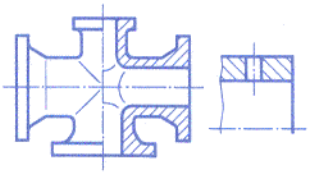

Sections in two parallel planes. In diagram I and II the hatched lines are drawn with equal inclination but they meet the centre line at different points, e.g. along the centre line.



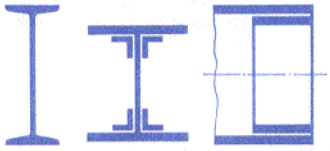
Parallel planes have a common but slanted connecting plane which is depicted in its projection.



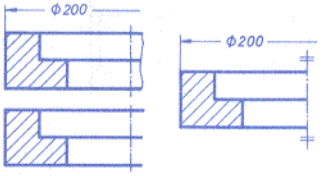

Sectional surfaces can coincide within the drawing on the plane. They are shown in light solid lines. At a different point in the diagram, they can be shown fitting into the projection. At another point, the angle at which it is tilted must be shown.



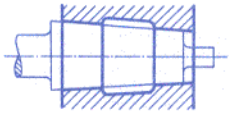
Rounded transitions of intersections (also rounded edges) can be shown using light solid lines. In the case of intersection of cylinders whose diameters are considerably different, flat curves of intersection can also be shown.



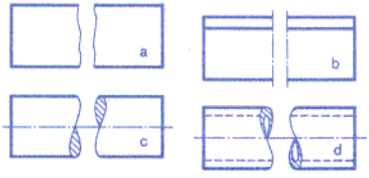
Small sectional areas can be fully blackened. If the surfaces clash with each other, they can be drawn at a slight distance from each other.



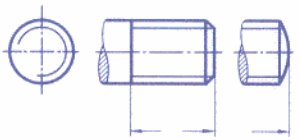

Symmetrical parts can be shown in a simplified way. The line of symmetry is shown by 2 short parallel lines.



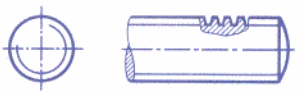
If representation of adjoining parts is necessary then the contours must be shown in thin solid lines.



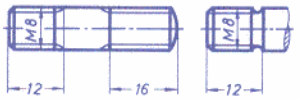

a. The objects can be shown as if they have been interrupted. The interruption lines can be shown in light solid lines.
b. In steel construction the interruption lines should also be shown as thin dash-dot lines.
c. Interruption of solid cylindrical objects.
d. Interruption of hollow cylindrical objects.



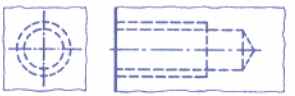
Threads are represented by small (thin) solid lines and in the side view by 3/4 circle through a thin solid line. Boundary lines: wide (thick) solid line. The conical and the oval ends are shown in the same way in the direction of the axis. The ends lie within the length of the thread.



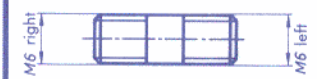
The thread forms e.g. trapezoidal threads particularly, can be specially depicted.
The 3/4 circle can also have a different position at the intersection of the axes.



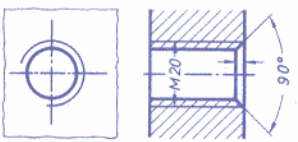

The runout of the thread lies outside the outer lines. It is shown and dimensioned only when necessary, e.g. for stud screws the runout of the thread belongs to the length of the thread.



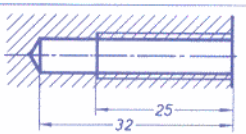
Covered (not visible) threads are shown in dashes.



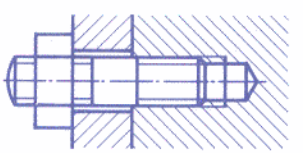

Left hand threads are depicted by the word "left". Right and left hand threads of the same diameter on the same part are shown either with "right" or "left" respectively.




Thread counter sinking is generally not shown or dimensioned. If the sinking is dimensioned, then the counter-sunk angle and counter-sunk diameter must be given. A counter sinking upto the outer diameter of the thread seen in the direction of the axis is not indicated.




For threaded holes, the depth of the core hole is given, and the active thread length must be shown without runout.

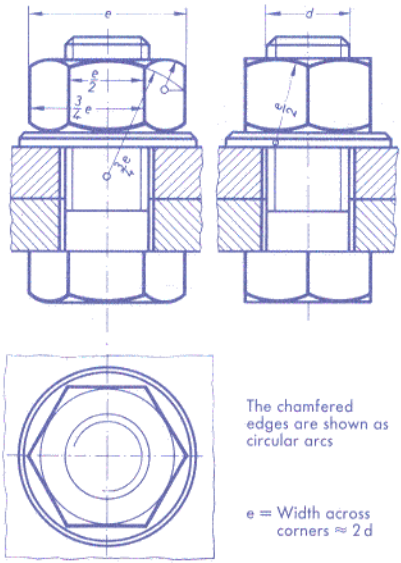


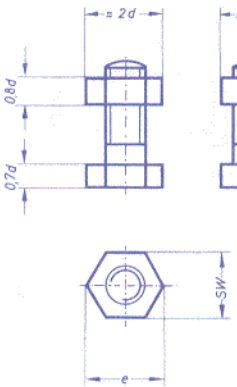
The boundary or outer line of the thread is shown both at the end of a stud screw or nut. In dimensioning the runout of the thread it is added the active thread length. Exterior threads cover the inner threads; shaded lines are to be drawn upto the broad, thick solid line.

| | |
|---|---|
| M 20 | Metric thread 20 mm; outer thread ⌀ |
| M 20×1,5 | Metric thread 20 mm; outer thread ⌀ x 1,5 mm pitch |
| R 4 | Withworth pipe thread with four inch nominal diameter of the pipe. |
| Tr 48×8 | Trapezoidal thread 48; outer thread ⌀ times 8 mm pitch. |

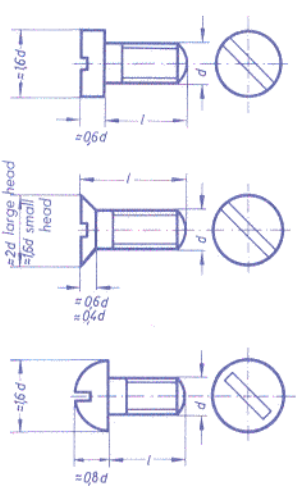
# Thread- and screw representations

DIN 27 (Mar. 67)




Width across flats SW ≈ 1.7 d
Width across corners e ≈ 2 d ≈ 1.155 SW

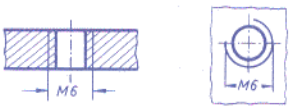



d = Thread diameter
l = Nominal length
Width of slot ≈ 0.2 d,
Depth of slot ≈ 0.3 d,
Slot to be drawn under 45°

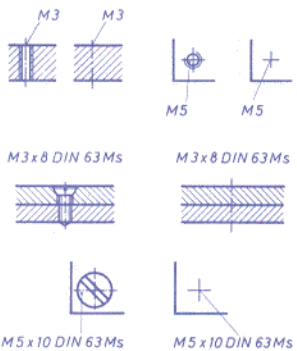
**Dimensioning of small representation**

DIN 30 (Dec. 70)

Drawn outer thread ⌀ > 5 mm




Drawn outer thread ⌀ < 5 mm



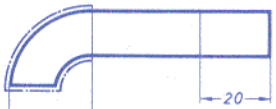
# Hardened parts

DIN 6773 (Oct. 67)

Diagrams and data for hardened (by uniform through heating), hardened through (by surface heating), and case hardened parts. These standards are not valid for representing hardness data of tool- and high speed steels.

*hardened: 600 HV 10*

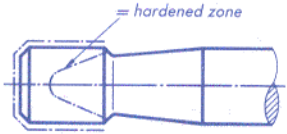
For hardening the entire piece, it is sufficient to use one term with an addition.
600 HV 10: Vickers hardness, test load 10 kg
Hardness number 600




*hardened: 600 HV 10*

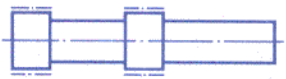
For local hardening, the hardened parts can be shown by broad dash/dot lines along the outer edge of the body and, can be dimensioned if necessary. For hardness data, units can be omitted for simplication.

For parts without a distinct hardness value and range, one term suffices.




*hardened: 600 HV 10*

If the core of the construction part remains soft, or if the hardening zone extends in a definite way, then this zone can be shown by a thin dash/dot line.



*hardened: (720 HV 10)*

*Eht (600 HV 10) = 0,6 ± 0,3*

Hardness values, which are specially tested, can be shown by an enclosure. Shown above or below near the title block: The ⬭ data are specially tested.

HD: Hardening depth f, example 0,6 mm. Tolerance ± 0,3 mm

*Case hardened: 800 HV 10*

*Eht (550 HV 10) = 0,5 ± 0,2*

For case hardening on all sides, one term with corresponding additional data is sufficient. The required depth of case hardening is shown with tolerance data.

# Surface details in the drawings

Surface symbols show the final state of the surface. Method of production is optional. If a particular method of production is desired, then the surface symbols are supplemented by the corresponding term. e.g. ground

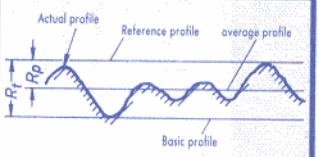
| as per **DIN 140** (10.31) | as per **DIN 3141** (Mar. 60) | | | | | as per **DIN 3142** (Mar. 60) |
|---|---|---|---|---|---|---|
| Surface symbol | Surface symbol | Maximum allowable surface roughness in $\mu$m Series 1 \| 2 \| 3 \| 4 | | | | Designation by roughness measure: Characterisation / Meaning |
| undressed | | arbitrary | | | | ① Average roughness $R_a$ $\mu$m ② Surface character as per DIN 4761: Method of production ③ Roughness measure e.g. Peak-to-valley height $R_t$ Smoothing depth $R_p$ |
| well forged, filed | | arbitrary | | | | |
| roughed | | 160 | 100 | 63 | 25 | **Example:** |
| finished | | 40 | 25 | 16 | 10 | $R_t = 10$ Maximum permissible Peak-to-valley height $R_t = 10\,\mu m$ |
| fine finished | | 16 | 6.3 | 4 | 2.5 | $R_p = 4$ upto 10 Smoothing depth $R_p$ between 4 and 10 $\mu$m |
| Scrutinising the surface with the naked eye, by touching, or with the use of model pieces for comparison. A clear scrutiny becomes difficult. | | – | 1 | 1 | 0.4 | $R_a = 4\,\mu m$ maximum permissible average roughness $R_a = 4\,\mu m$ |
| | In the title block or above it, the series which have been laid down must be given, e.g. Surface series 3 DIN 3141 | | | | | |
| | DIN 3141, 3142, scrutiny of the surface by comparing with the model piece. In special cases by measuring. | | | | | **Measuring roughness** DIN 4762 (Aug. 60) |

## Method of production and surface roughness

Attainable peak-to-valley height $R_t$ ($1\mu = 0.001$ mm)

| | | 1) | | | 1) |
|---|---|---|---|---|---|
| Sand casting | 63 | 25 | Reaming | 4 | 0,4 |
| Chilled casting | 25 | 10 | Surface grinding | 2.5 | 1 |
| Forging | 63 | 10 | Broaching | 2.5 | 0.63 |
| Drilling | 40 | 16 | Boring | 2.5 | 0.1 |
| Cutting | 10 | – | Longitudinal grinding | 1.6 | 0.1 |
| Facing | 10 | 2.5 | Long stroke honing | 1 | 0.04 |
| Milling | 10 | 1.6 | Polishing | 0.4 | 0.06 |
| Filing | 6.3 | 2.5 | Surface lapping | 0.25 | 0.04 |
| Shaping | 6.3 | 1.6 | Swing lapping | 0.16 | – |
| Planing | 6.3 | 1.0 | Short stroke honing | 0.1 | 0.04 |
| Longitudinal turning | 4 | 1.0 | Polish lapping | 0.04 | – |

1) Attainable in the case of special measures.




Peak-to-valley height $R_t$ is the distance of the basic profile to the reference profile.

Average roughness $R_a$ is the arithmetic mean of distance of the actual profile to the average profile.

Smoothing depth $R_p$ is the mean distance of the reference profile from the actual profile.

# Symbolic representations

Screws, rivets (for steel construction work)
Springs, toothed-wheels

DIN 407 (Jul. 59)
DIN 29 (Dec. 61)
DIN 37 (Dec. 61)

| M 8 | M 10 | M 12 | M 16 | M 20 | M 22 | M 24 | M 30 |
|---|---|---|---|---|---|---|---|
| 8,4 | | | | | | | 31 |

For steel construction, screws are shown by symbols upto the scale 1 : 5 in construction drawings. Above M 24 one shows a circle with data of the hole diameter. For machine construction: 17 etc.

| Tabular rivet Ø | | | | | | | |
|---|---|---|---|---|---|---|---|
| 8 | 10 | 12 | 16 | 20 | 22 | 24 | 27 |
| Hole Ø | | | | | | | |
| 8.4 | 11 | 13 | 17 | 21 | 23 | 25 | 28 |

Rivets with both sides snap headed, have a particular symbol for each diameter.

Above 25 mm diameter of the hole, the symbol is a circle giving details of the hole diameter.

Additional symbols:

With counter-sunk heads:

If top is countersunk — see *a*
If bottom is countersunk — see *b*
If both sides are countersunk — see *c*

Rivets to be hammered or screws to be drawn in at building site — see *d*

Rivet and screw holes to be drilled at building site — see *e*

For machine construction — 17 — etc.

| Both sides snap heads | | | | | | | |
|---|---|---|---|---|---|---|---|
| 8,4 | | | | | | | 28 |
| Counter-sunk heads | | | | | | | |
| 8,4 | | | | | | | 28 |
| *a* | | *b* | | *c* | | *d* | *e* |

DIN 29 (Dec. 61)

Diagram

Symbol

Pressure spring

Tension spring

Cup spring

single spring

spring pack

spring column

DIN 37 (Dec. 61)

Diagram

Spur gears

Worm wheel (assembly)

Bevel gears

Simplified drawing

Straight – helical gears

Generally it is not imperative to have the diagram of the dedendum

# Fusion welding, Joint welding, Build-up welding

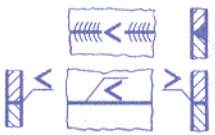
DIN 1912
Jul. 60/Mar. 61

## Types of Joints

| Butt joint | Lap joint (weld) | Parallel joint | T-joint | Cross joint | Slant joint | Corner joint | Multiple joint |
|---|---|---|---|---|---|---|---|

Welds (seams) can be shown by symbolic figure (welding symbols)
Diagramatic representation in view: beads and welding symbol in a section: cross section of weld, fully layed

Symbolic representation as view and as section:
Seam line with the welding symbol on the reference line.
If the seam is visible, then the welding symbol is put above.
If however, it is not visible (covered) it is put below the reference line.



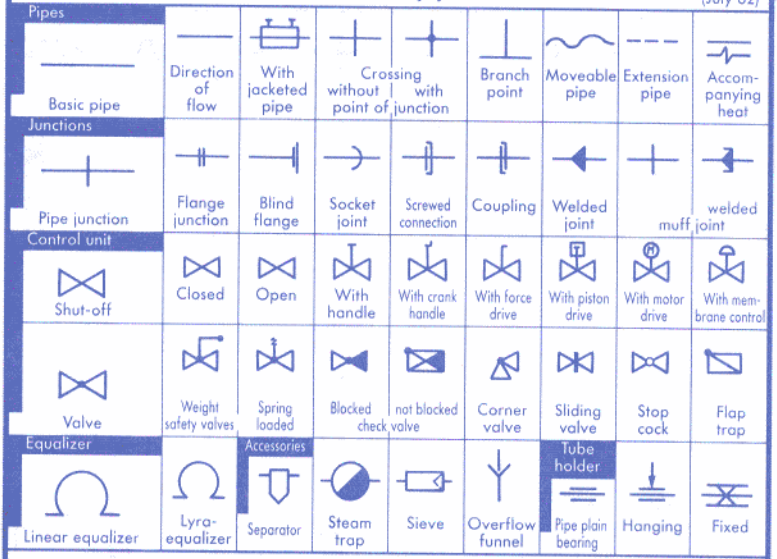
| Sym-bol | for seam form | Sym-bol | for additional data |
|---|---|---|---|
| | Border seam | | Plane level weld |
| II | I-seam | | Juncture worked |
| V | V-seam | | Hem welded |
| X | X-seam | | Fillet continuous weld |
| Y | Y-seam | | Assembling signs (for marking a weld to be done at the site |
| X | Double Y-joint | | |
| Y | U-seam | | Direction of welding process |
| V | HV-seam | 1 | Sequence of seam (with several seam |
| K | K-seam | | Flat weld |
| V | HY-seam | | Convex weld |
| K | K-web seam | | Concave weld |
| III | Frontal flush weld | | Common weld symbol (for welding seams without any particular data e.g. schematic representation available drawings) |
| | Fillet weld | S | |
| | Edge seam | | |
| | Build-up weld | S | |

Examples of graphical representation

| Nomenclature | Graph. representation section | Graph. representation view | Symb. representation section | Symb. representation view |
|---|---|---|---|---|
| General welding symbols | | | | |
| V-weld Hem-welded, countering weld a = s = 12 mm l = 110 mm | 12 | 110 | 110 12 | 12-110 |
| K-seam a = s = 30 mm | 30 | 140 | 140 30 | 30-140 |
| Fillet weld, juncture worked a = 8 mm l = 140 mm | | 140 | 8 140 | 8 140 |
| Fillet juncture (covered) a = 6 mm | | | 6 | 6 |
| Double fillet welded continuously | | 8 8 | 8 | 8 |
| Lap joint | | | | |
| Build-up weld | | | | |

## Symbolic representations for pipe installations

DIN 2429 (July 62)

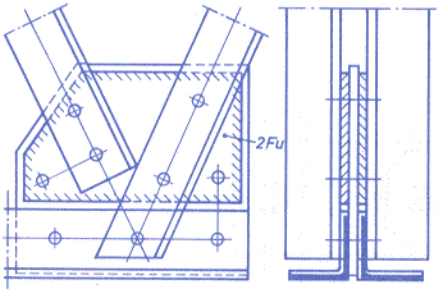



## Identification plates for pipe lines

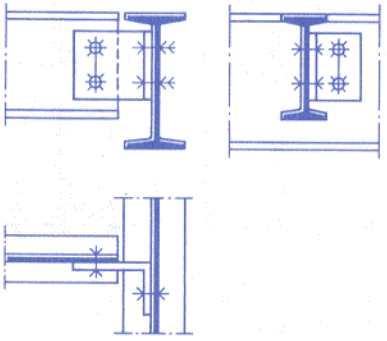
DIN 2403 (Dec. 53)

Pipe lines are marked in different colours depending on the medium passed through them. Specially for identification of inflammability, the arrow heads of group 4 & 8 are marked in red.

| Medium used | Group | Colour | Examples | |
|---|---|---|---|---|
| Water | 1 | Green | Drinking water 1.0 | 1.9 Waste water |
| Steam | 2 | Red | 2.1 Saturated steam | Heated steam 2.2 |
| Air | 3 | Blue | Fresh air 3.0 | Hot air 3.2 |
| Combustible gases | 4 | Yellow | Natural gas 4.0 | 4.1 Acetylene |
| Non-combustible gases | 5 | Yellow | Nitrogen 5.0 | Carbon dioxide 5.2 |
| Acids | 6 | Orange | Sulphuric acid 6.0 | Hydrochloric acid 6.1 |
| Lyes | 7 | Violet | 7.0 Caustic soda | Lime lye 7.3 |
| Inflammable liquids | 8 | Brown | Heavy oil 8.4 | Nitroglycerine 8.6 |
| Non-inflammable liquids | 9 | Brown | Milk 9.0 | Glue 9.5 |
| Vacuum | 0 | Grey | Vacuum 0.0 | High vacuum 0.1 |

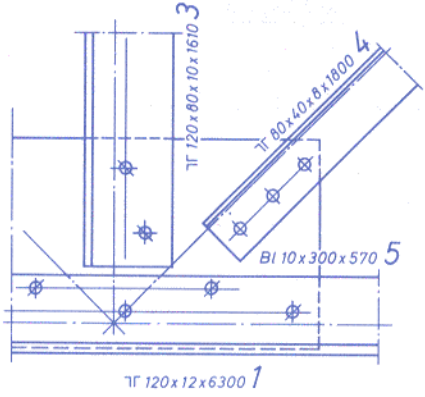



In a section, the packing is not darkened but hatched.
In views, the packing can be hatched for clarity. In the case of large packing objects, it suffices to have the edges hatched.
(The word packing or lining is commonly used for fillers made of lead which serve to fill up the gaps between the profiles).
Rivets are shown using solid lines in a side view.



As can be seen on the diagram on the left, screws are shown using broad lines. However, the ends are depicted with an angle of 90°.

If the side of the nut is shown, then the side has a double angle.

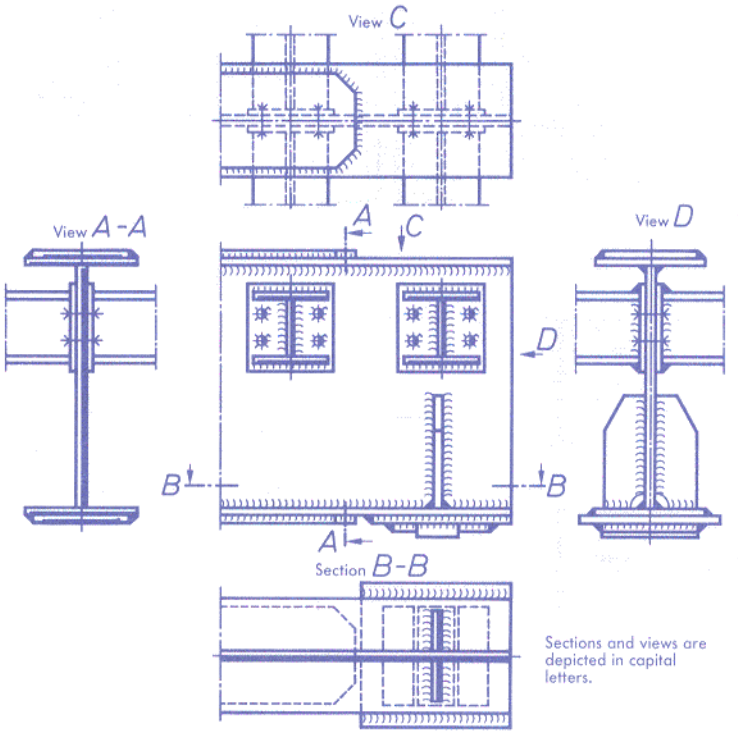



Axes of all members should intersect at a point, called the theoretical nodal point, so that the system lines coincide with the gravity lines. The short nomenclature of the bars (profiles) is put in the direction of the bar above, under or near the bar.
Part numbers are arranged clockwise if possible. They are always placed behind the nomenclature.
In the case of construction parts represented interrupted, the interruption lines are shown by dot-and-dash lines.

# Drawings for steel and light metal construction

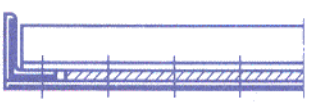
DIN 1034 (Jan. 67)

Drawings for riveted, screwed, welded, and cemented construction e.g. for bridges, crane work, high steel construction which deviate both representation and dimension from the general rules of drawing standards.

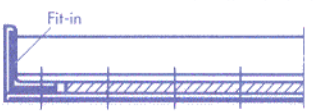



Sections and views are depicted in capital letters.

For a number of views or sections, the different views are arranged as follows: Top view of beam above the section, the bottom view of beam below, the right side view to the right and the left side view to the left.



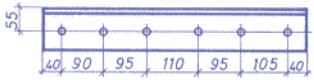
Section surfaces of profiles and sheets are blackened and have lighter edges. Profiles which do not fit are shown with a small gap from the adjoining constructional part.



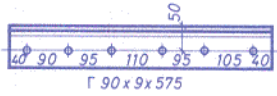

For fit-in profiles that do fit in and which can be shown without leaving a gap insert the word "Fit-in"

# Steel and light metal construction-dimensioning

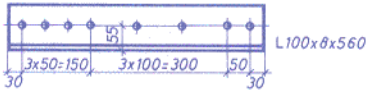
DIN 1034
(Jan. 67)



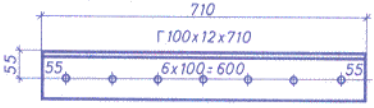

Dimension lines are drawn without gaps. The ends of the dimension lines are depicted by slanting lines. Points or arrow heads can also be used.



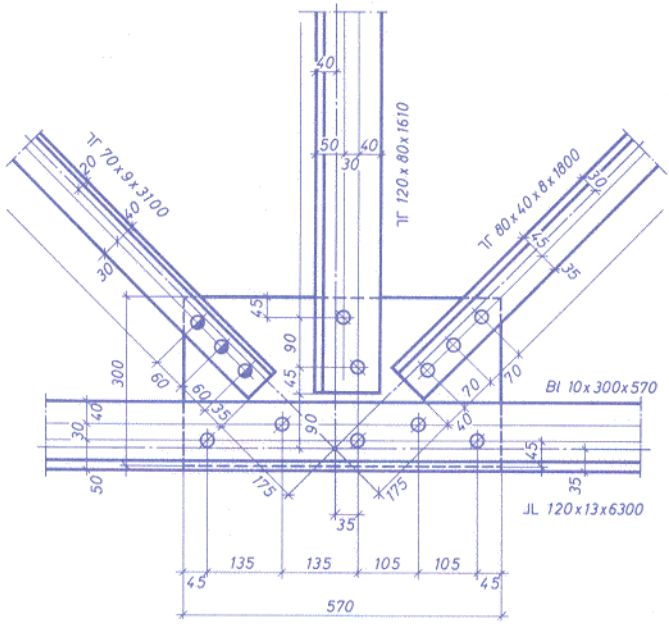

Dimension lines do not have to be projected out if the dimensions can be accommodated in between the symbolic figures.




Dimension figures should be put above the dimension line.
If there is a shortage of space, the dimension figures can be put above and below the dimension lines alternately.




In case of equal perforation symplified dimension chains may be inserted. For a series of similar rivets or screws, it is sufficient to put the symbol at the end of the series.

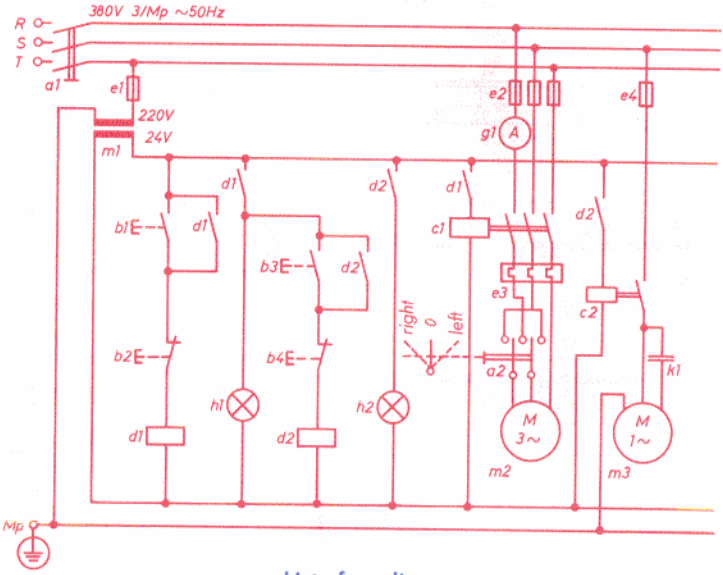



The symbols of the profile (L T ⊏ I) are generally inserted in such a way that the position of the profile is identifiable.

# Electric circuit diagram

DIN 40719 Additional Pg.1
(Sept. 57)

Example: The main drive of a tool machine depends on the main switch and an on-off knob for operation. It depends on the monitoring switch for clockwise and anti-clockwise running. The motor for the coolant pump should depend on the on-off knob for operation and should be independent from monitoring switches for clockwise and anti-clockwise running.




## List of appliances

a 1 Machine main switch
a 2 Monitoring switch main drive clockwise or anti-clockwise direction
b 1 On-knob for operation
b 2 Off-knob for operation
b 3 On-knob for pump
b 4 Off-knob for pump
c 1 Switching-on contactor for m 2
c 2 Switching-on contactor for m 3
d 1 Relay for operation
d 2 Relay for pump

e 1 Fuse for m 1
e 2 Fuse for m 2
e 3 Over current relay for m 2
e 4 Fuse for m 3
g 1 Current measuring instrument for m 2
h 1 Indicating lamp for operation
h 2 Indicating lamps for pumps
k 1 Condenser for m 3
m 1 Transformer
m 2 Main drive
m 3 Motor for coolant pump

## Identifying letters for types of appliances

| | Types of appliances | Examples |
|---|---|---|
| a | Switch | Power circuit main switch, motor switch, circuit breaker |
| b | Auxiliary switch | Push-button switch, monitoring switch, plug devices |
| c | Contactor | Power relay |
| d | Auxiliary relay | Auxiliary relay, time relay |
| e | Safety devices | Fuses, protective relay, tripping device |
| g | Measuring equipment | Voltage and current meters, counter |
| h | Light and sound indicator | Indicating lamp, alarm, horn, pointer instr. |
| k | Condensers | Inductance coils, condensers of all types |
| m | Machines | Motors, generators, transformers |

The nomenclature of each appliance is based on the identifying letters of the type of appliance and a subsequent ordinal.

# Electric circuit symbols

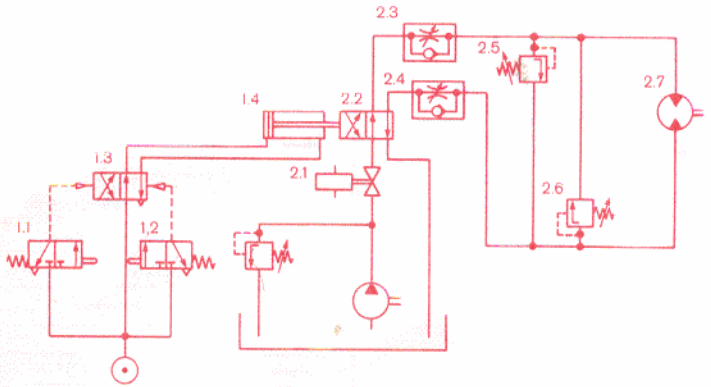
| Circuit-Symbols | Nomenclature |
|---|---|
| **Electricity** | DIN 40710 (Sept. 66) |
| --- or ═══ | Direct current |
| ~ | Alternating current |
| 1~ | Single phase alternating current |
| 3~50Hz | Three phase current |
| 3/Mp~50Hz | Three phase current with star connection |
| **Conductors** | DIN 40711 (Aug. 61) |
| ——— | Conductor (general) |
| ——— | Flexible conductor |
| ·—·—·—· | Protective conductor (e.g. Earthing) |
| ———/// | Conductor with number of leads |
| ——/// | Intersection of conductors without connection |
| • | Point of connection (general) |
| ○ | Detachable connections |
| **Switching devices** | DIN 40713 (Apr. 72) |
| | Stop, start switch |
| | Representing the point of connection |
| | Opener, break switch |
| | Changer, change switch |
| | Two way switch, closer with 3 connecting points |
| | Drive (e.g. relays) |
| | Fuse (general) |
| | Electro-mechanical drive |
| | Thermo relays |
| **Measuring instruments** | DIN 40416 (Feb. 70) |
| | Indicating measuring instruments |
| | Registering measuring instruments |
| A | Ammeter (unit ampere) |
| mV | Voltmeter (unit millivolt) |
| U ≈ | Voltmeter (for AC and DC) |
| VAΩ | Multimeter (voltage, current, resistance) |

| Circuit symbols | Nomenclature |
|---|---|
| **Additional circuit symbols** | DIN 40703 (Mar. 70) |
| --- or ═══ | Mechanically effective connection |
| 1 2 3 | Nomenclature of the position (2 = basic position) |
| ⊢------ | Hand driven (general) |
| E------ | Activating by pressing |
| F------ | Activating by turning |
| ------ | Other drives (e. g. foot) |
| ○------ | Contact for mechanical activation |
| □------ | Power drive (general) |
| **Further circuit symbols** | DIN 40712 (Jul. 72) |
| | Resistance (general) |
| | Variable resistance |
| | Coil |
| | Condensers (general) |
| | Permanent magnet (general) |
| | Primary element (battery) |
| | Earth (general) |
| | Protective connection |
| | Mass (general) |
| **Installation circuit symbol** | DIN 40717 (Jul. 70) |
| | Switches 1/1 (breaking switch) |
| | Switch 1/3 (3 pole breaking) |
| | Switch 6/1 (change switch) |
| | Switch 7/1 (cross-over switch) |
| | Knob switch |
| | Simple socket |
| 3 | Three way socket |
| 3/Mp | Protecting contact socket for 3 way current |
| | Lamp (general) |
| | Light indicator (signal lamp) |
| E | Electrical appliances (general) |
| | Electric cooker |
| | Micro-wave hearth |
| | Hot plate |
| + | Water heater |
| | Counter |
| | Pulse switch |

**Pneumatic circuits** VDI 3226 (Dec. 66)

**Basics:**
Preparation of a circuit diagram without considering the equipment arrangement, integration of sub-assembly in one diagram, division of pneumatic and electrical circuit in case of sub division in control chains near each other in the sequence of the motional course; equipments in control chain in the direction of energy flow: working cylinder and valves lying horizontally; pipings possibly straight and without crossings; numbering of the equipment e.g. 1.3; control chain 1; equipment 3.

**Example:**
The table of a machine tool is driven by a hydromotor. The rates of feed are adjustable in both directions separately and continuously. In both directions of rotation, the machine has a separated and adjustable torque limiter. The directions of motion can be switched over by tappet-actuated pneumatic valve. The hydraulic drive is switched off through an electro-magnetic valve.




**List of parts**

| | | |
|---|---|---|
| 2.7 | 1 | Hydromotor |
| 2.5, 2.6 | 2 | Pressure relief valve (adjustable) |
| 2.3, 2.4 | 2 | One-way restrictor (adjustable) |
| 2.2 | 1 | 4/2 directional control valve, (hydraulic) |
| 2.1 | 1 | Hydraulic stop valve (electrically operated) |
| 1.4 | 1 | Double acting cylinder (pneumatic) |
| 1.3 | 1 | 4/2 directional control valve (pneumatic) |
| 1.1, 1.2 | 2 | 3/2 directional control valve (pneumatic) |
| Serial No. | No. of parts | Nomenclature |

**Nomenclature and diagram symbols** DIN 24300 (Pub. Nov. 73)

**Energy conversion**

| | | | |
|---|---|---|---|
| | Hydropump | | Single acting cylinder |
| | Compressor | | Single acting cylinder, return stroke by spring |
| | Hydromotor | | Double acting cylinder |
| | Pneumatic motor | | Double acting cylinder with piston rod on both sides |
| | Hydraulic motor (adjustable) | | Double acting cylinder with damping on both sides |

# Oil hydraulics and pneumatics

## Nomenclature and Symbols

DIN 24300 (Pub. Nov. 73)

### Basic and functional symbols

| | |
|---|---|
| ——— | Working line |
| – – – – | Control line |
| – – – – – – | Vent line |
| | Firm connecting of piping |
| | Pipe crossing |
| | Direction of hydraulic effect |
| | Direction of pneumatic effect |

### Abbreviations for connections

| | |
|---|---|
| S | Inlet of pumps/compressors |
| P | Outlet of pumps/compressors |
| A, B | Connections on cylinders |
| A,B,C | Working connections on valves |
| P | Inflow to valve blocks |
| K | Working connection to valve blocks |
| R,S,T | Discharge vent |
| X,Y,Z | Control terminals |

### Energy transmission

| | |
|---|---|
| | Source of pressure |
| T | Point of vent |
| | Quick coupling |
| | Quick coupling with mechanically opened stop valves |
| | Container with piping upto underneath the liquid level |
| | Compressed air storage (lying) (standing = hydraulic) |
| | Filter with automatic water separator |
| | Oiler |
| | Stand-by unit. |

### Energy monitoring and control

The term passage valve stands for the number of connections and control positions.
e.g. 3/2-passage valve (= 3 connections, 2 control positions)

| | |
|---|---|
| | 2/2-passage valve with flow, zero setting |
| | 2/2-passage valve with shut off, zero setting |
| | 3/2-passage valve with shut off, zero setting |
| | 4/2-passage valve |
| | 4/3-passage valve with shut off, middle-setting |
| | 4/3-passage valve with shut off, middle setting |
| | 5/2-passage valve |
| | 5/3-passage valve with shut off, middle setting |
| | Pressure relief valve (adjustable) |
| | Pressure regulating valve (adjustable) |
| | Pressure regulator (adjustable) |
| | Back-pressure valve with spring |
| | Throttle valve |
| | Adjustable throttle valve |
| | Throttle back-pressure valve (adjustable) |
| | Stop valve |

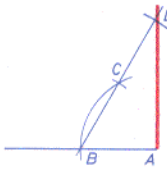
### Operations

| | |
|---|---|
| | Manually (general) |
| | By tappet |
| | By rolling knob |
| | By springs |
| | e.g. throttle valve, (adjustable). Manually operated |
| | By pressure |
| | By pressure-relief |
| | With an electro-magnet having a coil |
| | By an electro-magnet with 2 opposing coils |

# Basic geometrical constructions

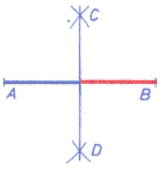
**To erect a perpendicular at point $A$.**

Draw arcs of same radius on both sides of point $A$ to get $B$ and $C$. Draw intersecting arcs from $B$ & $C$. Join the point of intersection $D$ with $A$. $DA$ is perpendicular to $AB$.



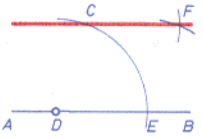

**To erect a perpendicular at the terminal point $A$.**

Draw an arc around point $A$. Using the same radius draw an arc around $B$ and then around $C$. Draw a straight line through $B$ & $C$ upto point $D$. $AD$ is a perpendicular to line $AB$.



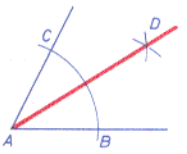

**To bisect a line**

Using the same radius draw arcs from point $A$ & $B$. The line $CD$ bisects $AB$ and is also perpendicular to it.



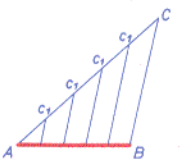

**To draw a line parallel to $AB$ through point $C$.**

Draw an arc around $D$ (at any point of $AB$) passing through $C$, draw arcs from points $C$ & $E$ using the same radius: $F$ is the point of intersection. $CF$ parallel to $AB$.



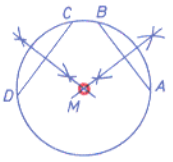

**To bisect an angle.**

Draw an arc with $A$ as centre. Now draw arcs of equal radius around the points of intersection $C$ & $B$. $AD$ bisects the angle into two equal parts.



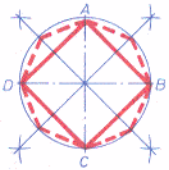

**To divide a line into equal parts (e.g.5)**

Draw a line of any length from point $A$. Now start dividing the line into equal parts, beginning from point $A$. Join the terminal point $C$ and $B$ and thereafter draw parallel lines through the points $C_1$.



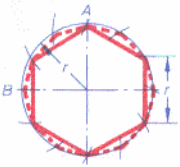

**To locate the centre of a circle or an arc.**

Draw any two chords through a circle: Choose a radius and draw arcs with points $A$ & $B$ as well as $D$ and $C$ as centre using the same radius each time (bisecting a segment). The intersecting point $M$ of the perpendiculars is the centre of the circle.



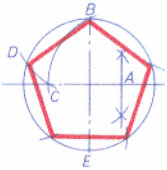

### Square Octagon

Join the points of intersection $A$, $B$, $C$, $D$, of the two perpendicular lines and circle to get the square. By bisecting the rigth angles one will get the other four points to complete the regular octagon.



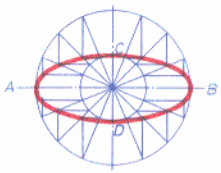

### Hexagon – Dodecagon

Divide the periphary by arcs of radius $r$ starting from point $A$ in 6 parts and join the points to each other to get the regular hexagon.
If one starts marking from point $B$ with the same radius one will get the additional corner points required to complete a dodecagon.



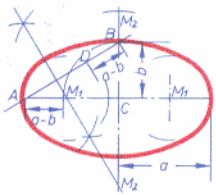

### Pentagon – Decagon

Draw an arc with $r = AB$ round $A$, the mid-point of the radius of the circle. $BC$ is the length of one side of the pentagon. Set off $BC$ fife times along the periphary.
If one starts marking from point $E$ with the same radius $BC$. One will get the additional corner points required to complete a decagon.



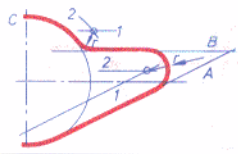

### Ellipse by means of two circles

Draw 2 circles having diameter $AB$ (major axis) and $CD$ (minor axis). Preferably draw a number of diameters. Now draw vertical lines from the points of intersection with the bigger circle, and horizontal lines from those of the smaller circle. The resulting points of intersection are points of the ellipse.



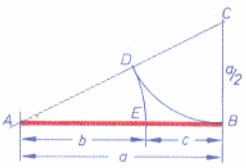

### Ellipse

Join $A$ to $B$.
Draw an arc with a radius $r = b$ around point $C$. On $AB$ cut the length $a\ b$ from $B$ to get $D$. The perpendicular on $AD$ intersects the vertical axis at $M_1$ and $M_2$ respectively, which are centres of the circles of the ellipse.




### Curvatures

Draw parallel lines 1 and 2 to the lines $A$ and $B$ as well as to $B$ and $C$ at a distance = $r$. The point of intersection is the centre point to make the curvature.

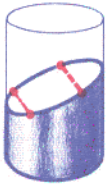


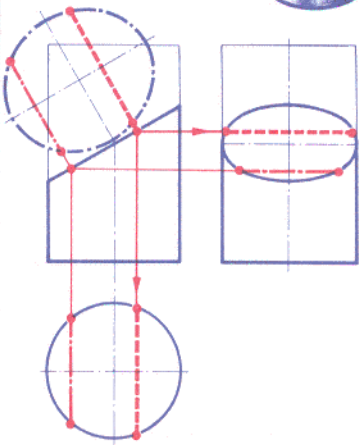

### Golden section of the line $AB = a$

Draw a perpendicular on $B$ and mark off $BC = a/2$. Draw an arc with $C$ as centre and using $BC$ radius to cut the line $AC$ at $D$. With A as centre and $AD$ as radius draw an arc to cut $AB$ at $E$, to get the golden section of the line, $AB$:
$a : b = b : c$ (=1000 : 618) constant proportion.

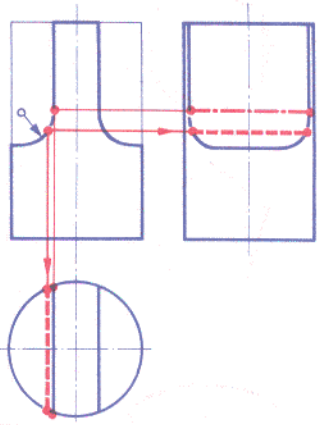
# Sections of solids

Inclined section of a cylinder gives an ellipse

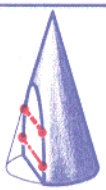


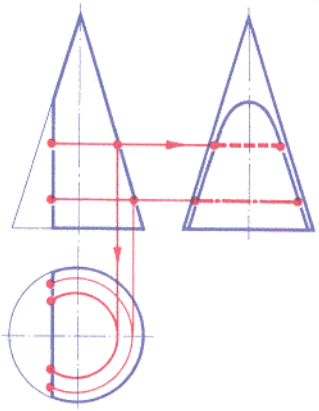


Flattening of a round steel with radius

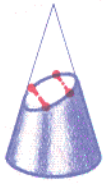


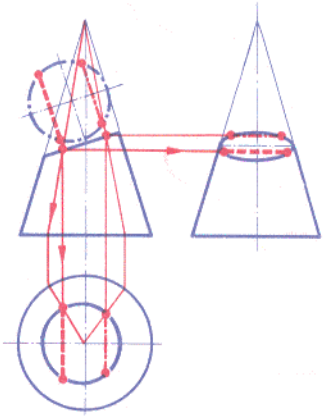
Cone section parallel to the axis gives a hyperbola





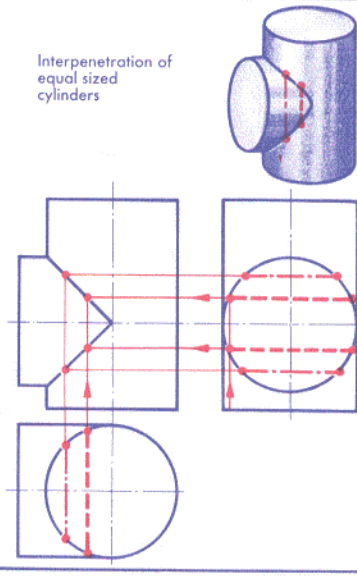
Inclined section of a cone gives an ellipse



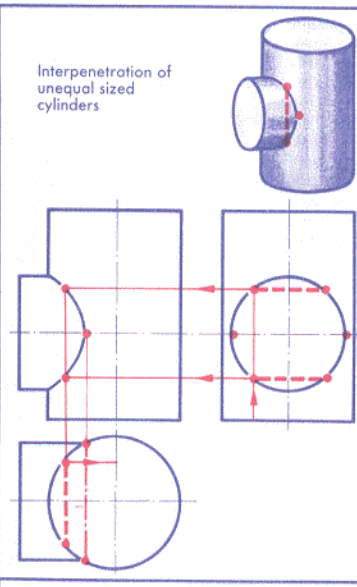


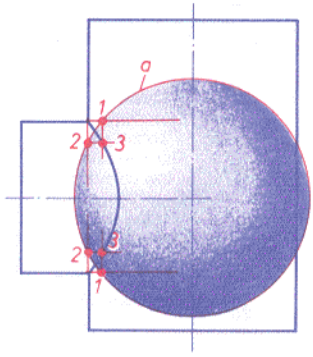
# Penetration

Interpenetration of equal sized cylinders



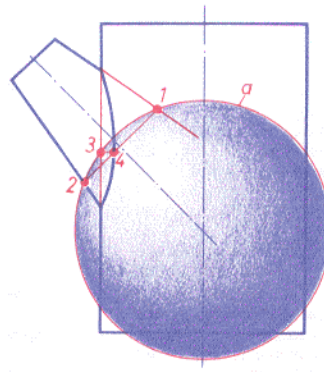
Interpenetration of unequal sized cylinders






Interpenetration of unequal sized cylinder: Spherical shell construction method

Origin of the point of interpenetration: Spherical shell *a* meets the smaller cylinder at point 1, the larger cylinder at point 2. The horizontal and vertical lines through the said points (1, 2) meet at point 3. (Point of interpenetration). Other points of intersection can be found by using spherical shells of larger or smaller radii using the same point as centre.




Interpenetration of the cylinder with an inclined cone: Spherical shell construction method

Origin of the point of interpenetration: Spherical shell *a* meets the cone at the point 1 & 2, and the cylinder at point 3.
Connecting straight lines between 1 & 2 of the cone together with the horizontal line of the cylinder give point 4 (point of interpenetration). Other points of interpenetration can be found using spherical shells of smaller or larger radii using the same point as centre.

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